BRITISH
SECRET PROJECTS
JET BOMBERS SINCE 1949

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To my old friend
Eric Morgan

British Secret Projects – Jet Bombers since 1949

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Photograph on half-title page:
Impression of the Royal Navy version of the Vickers Integrated Power Type 582 in its strike form. Brooklands Museum

Photograph on title page:
The first Buccaneer carrier take-off is made by development aircraft XK523 from HMS *Victorious* on 25th January 1960. BAe Brough

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Introduction and Acknowledgements

This book follows my first major work with Midland Publishing, *British Secret Projects: Jet Fighters since 1950*, and forms a natural companion to it. The design and development of the British Bomber since the end of World War Two is examined in similar depth with particular emphasis placed on the tender design competitions between projects from different companies. The sub-title date, 1949, relates to the first flight of the English Electric Canberra, Britain's first jet bomber, but of course studies were under way several years prior to this.

Once again extensive use has been made of previously unpublished primary source material held by museums and record offices and in company and private collections, much of it recently declassified. Consequently it is again possible to reveal more of the Government's side of events than has probably ever been included before in a publicly available book, and give an insight into a secret world where few had any idea of what was happening. Some of the factors and arguments that led to certain types either being cancelled or chosen for production and service are also reported, often for the first time.

This book brings together many little-known projects within a full narrative of bomber development. Plenty of bomber projects have been drawn by British companies over the last fifty years, particularly before the formation of the British Aircraft Corporation and Hawker Siddeley Aviation, but few were turned into hardware and little has been previously published about most of them. Bombers are more expensive than fighters and 'paper plane' competitions were crucial to acquiring the best aircraft yet, such were the advances in aerodynamics in the years after the end of World War Two, four competing medium bombers were actually built and flown to give Britain the V-Force. The main lines of design absorb by far the majority of this book but space is also devoted to less obvious types such as the anti-submarine aircraft.

Most of the projects shown here would have been tunnel tested but it is impossible to say from the evidence available if they would have worked (although any design sent to the Air Ministry would be expected to fly). Few designs that did not at least reach wind tunnel testing are worthy of historical attention. Project data throughout this book is the manufacturer's estimates. If submitted to the Ministry, the figures would normally be re-assessed by specialists and often changed (the weights in particular would regularly increase) but using company data as much as possible provides a common factor to presenting figures.

I think it is correct to state that few, if any, large bomber designs (medium and upwards) have been produced in Britain since TSR.2; an interdictor strike aircraft such as Tornado was about the biggest programme the country could afford to take on. From about 1960 onwards there has been a great deal of effort towards producing multi-role aeroplanes with both fighter and bomber capability. Often it has been difficult to find a demarcation line because there was so much overlap and, consequently, one has to decide if a project should be in a fighter or bomber volume. By the time AST.396 was reached one or two projects were under way, such as Brough's P.153, that were indeed more fighter than bomber but they have to be included in this volume for completeness. In fact, because they were integral to both stories, the Hawker P.1154 and Supermarine Scimitar feature here and in the companion *British Secret Projects: Fighters*.

The bomber is perhaps one of man's most unpleasant creations but many times they have proved to be a vital element within his armed forces. Technically and politically they can be captivating subjects while certain examples can inspire affection on a remarkable scale (witness the popularity of the Avro Vulcan at air shows); why is it that some of man's most beautiful creations are killing machines? Regardless of such arguments it has been fascinating to write about them and I hope those of you who sample this book enjoy reading it as much as I have enjoyed writing it.

Tony Buttler MA, AMRaeS, AMIM,
Bretforton, January 2003

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Chapter One

Mosquito Replacement

English Electric Canberra B Mk.6 WJ764 photographed in about 1954. It displays the modified fin and was later converted to B Mk.16 standard.

Britain's First Jet Bomber: 1944 to 1951

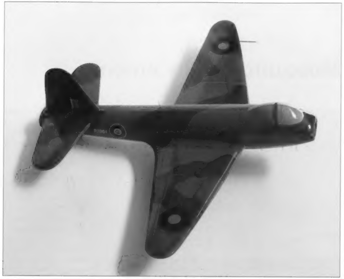
In 1945 Great Britain possessed a huge and immensely powerful strategic bomber force which had shown itself to be capable of all manner of bombing operations, from near wiping out complete cities to delivering 10-ton bombs from great height to hit pinpoint targets with great accuracy. As a weapon of war this was of immense strategic value. However, during the last year or so of the Second World War both Allied and Axis air forces had put jet-powered fighter aircraft into service, which meant that the piston-powered Avro Lancaster and its sisters would be obsolete pretty quickly. Britain was still to field replacement piston bombers in the shape of the Avro Lincoln and American B-29 Washington but, once the new power source began to offer better range (early jet engines were notoriously heavy on fuel), then jet bombers had to be the way forward.

The replacement of the strategic force machines would lead to the V-bombers but there was another handy chap also made obsolescent by jet fighters that needed replacing. This was the de Havilland Mosquito which could accurately be described as the world's first multi-role aircraft. Designed as a very fast unarmed bomber its speed and performance had ensured it found service as a fighter, bomber, fighter-bomber, anti-shipping aircraft, photo reconnaissance type and, after retirement from the front line, many other secondary duties. Therefore, quite naturally, Britain also concentrated on finding a replacement 'Jet Mosquito' and it too was to prove so successful that many different versions were produced though, initially, it was considered to be more of a strategic bomber.

Westland P.1056 and P.1061

When the English Electric Canberra made its first flight in May 1949 it became the first jet bomber to be built and flown in the UK. The work leading up to it, however, had begun over five years earlier, not in the north of England but in the south west in Somerset. In March 1944 Westland Aircraft's Technical Director, W E W Petter, had completed a private venture design study for a high-speed twin jet-powered fighter-bomber in two versions. This followed discussions between the company and two members of the Ministry of Aircraft Production (MAP) – Sir Wilfrid Freeman and N E Rowe (DTD).

The principal difference between the two projects lay in their undercarriage; P.1056 had



Model of the Westland P.1061 project made by Joe Cherrie Snr (3.44).

the tailwheel arrangement used by most piston aircraft whereas P.1061 introduced a tricycle undercarriage with a nosewheel. Power was supplied by a pair of 3,500lb (15.6kN) Metropolitan Vickers (MetroVick) F.2/4 Beryl axial jet engines mounted side-by-side in the centre fuselage and fed by a large nose intake. To avoid the tailwheel P.1056 ejected its exhaust through holes in the side of the fuselage ahead of the tailplane but the tricycle gear meant P.1061 could have a more effective single pipe at the very end of the fuselage serving both engines. Both single and twin fins were examined.

Each had two crew seated side-by-side in a cockpit placed close to the nose to give an excellent view, four 20mm cannon mounted in the lower forward fuselage and a large internal bomb bay situated behind the engines and beneath their exhaust pipes for carrying up to six bombs or other loads including rocket projectiles. P.1061's span was 56ft 6in (17.2m), wing area 550ft^2 (51.2m^2) and all-up-weight 32,000lb (14,515kg). Predicted top speed was 520mph (837km/h) at 25,000ft (7,620m). The idea generated much interest and a mock-up was built of the nose and central fuselage, while Petter had on his desk a scale model complete with bombs, engines and other internal fittings.

The project died when Petter left Westland but he took the jet bomber idea with him. It appears Petter had become frustrated with the direction that his company was moving (it had started work on a large naval fighter which was later developed into the Wyvern) and in September 1944 he joined English Electric at Preston (with Westland's agreement). Anthony Furse's book *Wilfrid Freeman* states that 'Freeman rescued the project by arranging for Petter to join the new English Electric aircraft team as Chief Designer' so one assumes that Westland's directors were not happy with the jet fighter-bomber.

English Electric High-Altitude High-Speed Unarmed Bomber (one engine)

Following his arrival at English Electric Petter progressed the bomber concept towards a preliminary specification, based on the requirements of the Air Staff, to replace the Mosquito bomber. The fitting of defensive guns was dropped and on 2nd February 1945 he told Rowe: 'The company welcomes the opportunity to carry out design investigations of a high-speed unarmed bomber'. A preliminary study was completed by 8th March and Petter reported that he 'believed a machine weighing not more than 40,000lb (18,144kg) can comply with the specification'. The full design brochure was ready on 1st June to the following specified limits:

i. Cruise speed of 500mph (805km/h) at an altitude of between 35,000 and 45,000ft (10,668 to 13,716m).
ii. Still air range of 1,600 miles (2,574km).
iii. 6,000lb (2,722kg) bomb load.
iv. Two crew.

The specified cruising speed was, in fact, so high that at 40,000ft (12,192m) it corresponded to about three quarters of the speed of sound (Mach 0.75) and so very special consideration had to be given to all drag excrescences, wing thickness and the intersection between body and wing and tail. The 40,000lb weight was confirmed which, to obtain 500mph, would require 12,000lb (53.3kN) of jet thrust. This would need a fuselage to accommodate two or even three existing type engines, each at least 4ft (1.22m) in diameter, giving a large cross-sectional area. Thus the multi-engine arrangement had a frontal area governed by the engines and in excess of that required for crew and load.

Hence, discussions looked at what thrust could be obtained from a single engine, without exceeding the size of forgings and other parts which could be manufactured from present equipment, and consultations with Rolls-Royce concluded that an engine of 66in (168cm) diameter appeared to be feasible and such an engine in two-stage form could produce the required 12,000lb thrust. This offered very considerable savings in items such as jet pipe weight, fuel and control systems while, further, a single engine would cut drag and provide even better performance thus reducing the likelihood of interception. It was to be housed in a circular-section fuselage which offered low drag at the wing and tail intersections.

The proposed engine was of the two-stage centrifugal type producing 12,500lb (55.6kN) static thrust and was more than 12% more efficient in its use of fuel than existing types (the document gives no title to the proposed engine but it was almost certainly the RB.43). Air was fed through two wing ducts and, due to the aircraft's fairly large size, it had been possible to arrange these very efficiently. The jet pipe was made in light Inconel (nickel-chromium-base) alloy sheet.

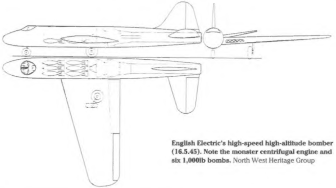
The body between the crew's pressure cabin and the engine was divided into upper and lower compartments by a 'floor'; the upper for fuel and lower for a long bomb bay. All fuel was housed in the fuselage (space was available in the wings for any additional capacity that might be required) and, although the front bombs were forward of the CofG, it was felt that the aircraft was so disposed that even with bombs gone there was still an ample margin of stability. It was not anticipated that any difficulty would be experienced with CofG shift should all bombs be dropped simultaneously but it was proposed to undertake a simple flight test on an existing aircraft to prove this point.

The cabin pressure provided for the crew would give an equivalent of not more than 25,000ft (7,620m) at all times (Petter had much experience of high-altitude aircraft pressure cabins after his work on the Westland Welkin piston fighter). Semi-monocoque construction was used for the centre (and rear) fuselage with the upper portion filled by a 1,165gal (5,297lit) self-sealing bag fuel tank. The bomb bay beneath could accommodate, as typical loads, six 1,000lb (454kg) bombs, one 4,000lb (1,814kg) or a combination of two 1,000lb and eight 500lb (227kg) bombs. Another 500gal (2,273lit) bag fuel tank was placed in the forward part of the rear fuselage while the fin was made integral with the rear fuselage structure.

The tailplane was made in two halves and was to have electrically actuated variable incidence; the flying controls were horn balanced with spring tabs. A single main spar was used in the low-position wing and it was planned to combine simple construction with a complete absence of spanwise joints in the plating as far back as 40% chord from the leading edge. The nose plating consisted of special sheets 3ft (91cm) wide and up to 15ft (4.57m) long wrapped around the leading edge from top to bottom spar boom. Aspect ratio was 5.4. The main wheels retracted into the wings but the nose leg needed to rotate through 90° to comfortably sit horizontally beneath the cockpit.

Maximum weight was 43,800lb (19,868kg) of which 19,500lb (8,845kg) comprised bombs and fuel and at this weight maximum speeds were 533mph (858km/h) at sea level, 541mph (870km/h) at 10,000ft (3,048m) and 504mph (811km/h) at 40,000ft (12,192m); sea level rate of climb was 4,260ft/min (1,298m/min) rising to 7,370ft/min (2,246m/min) when the machine was light at 28,000lb (12,701kg). At these weights times to 10,000ft were 2.7 and 1.6 minutes respectively; to 40,000ft 18.9 and 9.8 minutes, and service ceiling (100ft/min [30.5m/min] climb) 43,500ft (13,259m) and 48,500ft (14,783m). Take-off wing loading was 42.0lb/ft^2 (205kg/m^2). Petter confirmed that every endeavour had been made to keep the machine as small and as fast as possible, consistent with the very high cruising altitude.

Model of the high-altitude bomber made by Joe Cherrie Snr.



English Electric's high-speed high-altitude bomber (16.5.45). Note the monster centrifugal engine and six 1,000lb bombs. North West Heritage Group

English Electric High-Altitude High-Speed Unarmed Bomber (two engines)

On 9th July 1945 Petter informed MAP: 'Since sending our drawing we have heard from Rolls-Royce that they have progressed with a very efficient axial flow engine'. Petter had discussed this with Hives at Rolls the previous week and he could report that 'in consequence we are working out two alternative proposals – although both have approximately the same performance and size, the alternative may possess advantages that you may prefer'. A second brochure appeared later in the month using two Rolls-Royce Small Diameter (Axial) Jet Engines of 6,500lb (28.9kN) thrust each. The rapid development of this type, over just a few weeks, made it possible for Rolls to confidently offer new units which, for a given thrust, were of smaller diameter, about 30% lighter and with fuel consumption 5-10% better than the best previously envisaged. This was due to the perfection of high-speed axial flow compressors in place of the centrifugal type. Petter and his team had automatically re-examined his original design and produced an alternative and improved proposal.

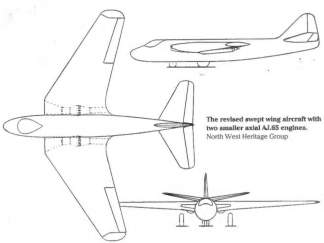
The narrower engines meant they could be

housed almost entirely within the wing roots, an arrangement previously considered near impossible on account of the large engine diameters. Situated here they had very short and direct high-speed entry ducts and tail pipes; twin-engine reliability was also provided. This arrangement also offered rather more flexibility in regard to future engine developments although to 'bury' the engine the wing section thickness had been blown up to 15% overall at the root. The main wheels had been moved much nearer the centreline and, in the fuselage, the changes were very beneficial.

The disappearance of the fuselage engine and raising the wing made possible a long uninterrupted bomb bay on the CofG 6ft (1.8m) wide and 24ft (7.3m) long and a maximum 3ft (91cm) deep. This made for extreme flexibility in choice of bomb load ranging from a large number of small bombs up to one 8,000lb (3,629kg) bomb, but including the specified six 1,000lb (454kg). For the same reasons the fuel tanks above the bomb bay were simplified, brought closer together and reduced in size, by reason of the lower consumption, to 1,500gal (6,820lit) total internal fuel. Elimination of the fuselage jet pipe made possible a simpler and lighter adjustable tailplane and saved considerable weight aft; as the engine weight had also moved forward, balance could be maintained with a shorter front fuselage. The compressor at the front of the engine projected through the wing spar so the unit would be withdrawn rearwards and downwards.

These changes, together with a reduced engine and fuel weight, had cut all-up-weight by over 10% to 39,300lb (17,826kg) (including six 1,000lb bombs and 11,500lb [5,216kg] fuel) while wing area was down to 950ft^2 (88.4m^2) without increasing wing loading. The aspect ratio was slightly reduced to 4.9. After discussions with radar specialists the pressure cabin layout had been improved with the navigator-radar operator now seated behind the pilot, facing forward. The radar scanner was housed entirely within the lower half of the nose while the twin nosewheel had been moved so as to retract vertically behind the pressure cabin bulkhead.

At maximum take-off weight (39,300lb) maximum speeds were 542mph (872km/h) at sea level, 547mph (880km/h) at 10,000ft (3,048m) and 506mph (814km/h) at 40,000ft (12,192m); sea level rate of climb was 4,800ft/min (1,463m/min) rising to 7,950ft/min (2,423m/min) when the machine was light at 24,900lb (11,295kg). At these weights times to 10,000ft were 2.3 and 1.5 minutes respectively; to 40,000ft 15.6 and 8.4 minutes, and service ceiling (100ft/min [30.5m/min] climb) 44,700ft (13,625m) and 50,300ft (15,331m). Take-off wing loading was 41.4lb/ft^2 (202kg/m^2). In reply Rowe wrote that a 'big improvement has been obtained compared with the original layout using one large engine housed in the body. In particular the bomb bay is not restricted and can be made to carry a wide variety of bombs of the latest design'.



The revised swept wing aircraft with two smaller axial AJ.65 engines. North West Heritage Group

A second alternative layout used wing sweepback. A sweep angle of about 30° at the quarter chord line had attractive features such as raising the 'critical speed' at 40,000ft (12,192m) by about 35mph (56km/h). However difficulties such as early tip stalling, which was at the time proving troublesome in sweptback tailless layouts, were anticipated and there would be an increase in wing structure weight. Since the cruising and even maximum speeds were not very seriously affected by compressibility effects with the present available thrust, English Electric did not yet consider it essential or even, at this stage, desirable to adopt the sweptback form. However, this was considered to be a most promising development and one which, with the same basic aeroplane, made possible a further big step forward in conjunction with an improved engine later on. An all-moving tail unit might also be introduced at the same time.

In discussion with the author, British Aerospace, Warton, suggested that the original centrifugal engine was not very practical for this type of aircraft. The first arrangement with, essentially, a much uprated Nene in the mid-fuselage position near the wing trailing edge was perhaps the worst place to put the engine because it was in the CofG where the payload should really go. The axial engine was much better, offering growth potential, and so when Rolls proposed the early model Avon, Petter put two in the wing roots. Wing sweep was not worthwhile here since the Mach number required did not need it and such a modification would increase structure weight. Three months later Petter moved the engines into neat and tidy wing nacelles as a final solution, leading to the machine we all know today.

English Electric A.1 Canberra

The first draft of AST.199 was produced in September 1945; the first issue of the full OR.199 was released in January 1946 with specification B.3/45 to cover it drafted the previous November. Intended to be a replacement for the unarmed Mosquito, it would be 'complementary to a long-range high-speed armed bomber' also currently being discussed (Chapter Two). A contract for the design and construction of four prototypes of the English Electric A.1 to B.3/45 was awarded in December 1945, A.1 being derived from the SBAC numbering system; later versions of the aircraft would have been the A.2 and A.3 but the name Canberra was given instead. The first public reference to 'a twin-engined jet bomber' was made in March 1949, but without specifying the type or manufacturer, and the first prototype made its maiden flight on 13th May.

The first Canberra prototype seen with its original rounded rudder and dorsal fin, a feature that was quickly modified. North West Heritage Group

The aircraft was seen as a considerable advance, both in speed and operating height, over any existing type. By 1947/48 it was intended that the high-altitude light strategic A.1 would be an interim replacement for Bomber Command's Main Force of piston aircraft pending the introduction of the greater-range types. A blind bombing aid was needed for this role and the entirely new H2S Mk.9/NBC (Navigation and Bomb Computer) Mk.2 was specified.

In July 1949 it was reported that this equipment had been delayed to a date when it would be required simultaneously by both the Canberra B Mk.1 and the Vickers B.9/48 medium-range bomber (later the Valiant). As only one type of blind bomber was required and since the production date of the B.9/48 compared favourably with that of the fully equipped Canberra, the development effort for H2S/NBC was, therefore, fully devoted to the B.9/48 and further development of Canberra Mk.1 was cancelled. ACM the Hon Sir Ralph Cochrane, Vice Chief of the Air Staff (VCAS), decided that since B.3/45 H2S could not be ready before the B.9/48, the former 'is no longer an Air Staff requirement' and production of English Electric's blind bomber was not required. With the entire nose taken up with H2S and its scanner, the type could not be used for visual bombing. Fortunately for the makers, other versions were on their way.

In February 1947 the Air Staff stated a requirement for a tactical day bomber variant to replace the de Havilland Mosquito and Bristol Brigand tactical day bombers in the RAF's Middle East and Far East Air Forces. To evade enemy defences, this was to rely on high speed, good manoeuvrability and a rearward warning device. Specification B.5/47 and OR.235 were written around the type in November 1947. Maximum speed at 20,000ft (6,096m) was not to be less than 440 knots (815km/h) with cruise speed not less than 390 knots (723km/h). Range was to be at least 1,000nm (1,852km) and maximum bomb load 7,500lb (3,402kg), with delivery by a Visual Automatic Computing Sight. It had three crew and no defensive weapons.

Cochrane wrote that there had been 'a tendency to look upon the Canberra as a long-range high-flying bomber' when 'it was generally accepted that [it] is a short-range tactical bomber [and] that there is no equipment which will enable it to hit a small target from 45,000ft'. As early as April 1948, before B.3/45 was cancelled, it was realised that the tactical B.5/47 would be in production first. As the B Mk.2 the new type entered RAF Service in May 1951, the prototype (the fifth Canberra) having flown on 23rd April 1950. The original concept had been much scaled down and its weapons comprised one 5,000lb (2,268kg), two 4,000lb (1,814kg), six 1,000lb (454kg) or mixtures of smaller bombs. The much larger aircraft to be described in Chapter Two was expected to become the RAF's primary bomber but it would be clearly uneconomic to use this for many expected short-range tasks, so the smaller Canberra type was still an important addition to the service (in the event, a greater proportion of the RAF's bomber force was to equip with Canberras than V-bombers).

A photographic reconnaissance variant PR Mk.3 was built to PR.31/46 and OR.223; the next bomber variant was a target marker to Specification B.22/48 and OR.263 to replace the pathfinder Mosquito B Mk.35 still held by Bomber Command. Although the requirement called for a primary role of visual target marking at low level, it did say that the aircraft should have a secondary role as a light bomber. Operating height was to be between sea level and 40,000ft (12,192m) with maximum and cruise speeds at the upper level again 440 knots and 390 knots respectively. Up to 2,000lb (907kg) of target indicators or

The Canberra prototype gets airborne for the first time on Friday 13th May 1949 – the first flight of Britain's first jet bomber.

The prototype of the B(I) Mk.8 two-seat night interdictor/tactical bomber Canberra was VX185. Converted from the B Mk.5 prototype with offset fighter-style canopy, VX185 first flew in this form on 23rd July 1954.

6,000lb (2,722kg) of bombs were to be carried. The prototype flew on 6th July 1951 but no orders for the variant, the B Mk.5, were forthcoming. Instead versions followed to cover the interdictor and reconnaissance roles.

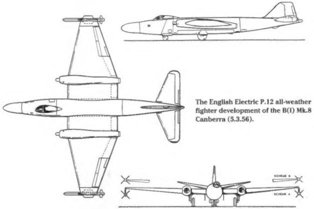
Progress with the aircraft's engines did not go to schedule either. It was not until 25th March 1947 that the AJ.65 (Avon RA.1) first ran on the bench and then well below the specified 6,500lb (28.9kN). Such were the delays in getting it flightworthy that the second prototype, VN813, was adapted to take Rolls centrifugal Nene engines to enable flight testing to begin on time. Studies were made in July 1948 comparing the AJ.65 with an 'interim' Avon of 5,500lb (24.4kN) thrust, the Nene II at 5,000lb (22.2kN) and a re-rated Nene at 5,500lb. Respective cruising speeds were 435, 420, 360 and 400 knots (806, 778, 667 and 741km/h), and cruise altitude at 40,000lb (18,144kg) weight 40,500, 36,500, 31,500 and 33,000ft (12,344, 11,125, 9,601 and 10,058m). Still air range with normal fuel and bombs fell from 1,800nm (3,335km) for the AJ.65 to 1,290nm (2,390km) for the Nene II; clearly the Nene was much inferior but, in the event, the first flight was made using Avon power. The modified RA.2 gave 6,000lb (26.7kN) in 1948 and was cleared to fly in the A.1 in January 1949 (VN813 flew with Nenes on 9th November 1949).

English Electric P.12

English Electric appraised its new aeroplane on 25th July 1947. 'Known initially as the "Mosquito Replacement", the development of this larger and faster aircraft had shown considerable similarity to the Mosquito in some respects and it is apparent that the production of a high-speed aircraft of medium range and a useful carrying capacity, in which defence depends upon provision of the best possible performance, lends to many uses in directions other than those originally contemplated. Already, in addition to the strategic high-altitude bomber, a photo reconnaissance, a low-altitude tactical bomber and a trainer are being built or are already investigated, and it seems certain fighter roles could also be filled by this aircraft'.

It is worth taking a quick look at a proposed fighter Canberra. In June 1949, with just 12 hours of test flying completed, test pilot Wg Cdr R P Beamont had written that 'with only minor modifications to the existing design a night fighter variant could be produced for Squadron Service...which would compare favourably in performance with the proposed interim types [de Havilland Vampire and Gloster Meteor], and would most probably exceed them in rate of climb, endurance, operational ceiling and firepower'.

The P.12 all-weather fighter was dated 5th March 1956 and utilised the B(I) Mk.8 Interdictor's basic fuselage. It had 11,250lb (50kN) Avon RA.24s (13,500lb [60kN] RB.126 units were directly interchangeable), AI.18 radar and was armed with two Vickers Red Dean air-to-air missiles carried under the wing tips. This study was made with General Electric at Stanmore and with Vickers; Boulton Paul would be responsible for the installation work. Somewhat surprisingly, the study revealed an interception performance equal or superior to any aircraft that could operate this system before it was superseded. This was due to the high performance intended for Red Dean and the ability of Canberra to carry the complete system to an adequate speed, just short of buffet and other transonic problems, without suffering the endurance, stowage and other difficulties of a supersonic aircraft. In addition, the all-round scan of the missiles mounted at the wing tips would be very important for a fighter that may have to attack targets faster than itself. A fully equipped prototype would be ready in March 1958. Span was 67ft 3in (20.5m), length 68ft 7in (20.9m), all-up-weight with two Red Dean plus guns 41,771lb (18,947kg), maximum level cruise Mach 0.9 above 11,000ft (3,353m) to 50,000ft (15,240m), sea level rate-of-climb 12,500ft/min (3,810m/min) (17,500ft/min [5,334m/min] for RB.126), time to 40,000ft (12,192m) 5.1 minutes (3.6 minutes for RB.126).



The English Electric P.12 all-weather fighter development of the B(I) Mk.8 Canberra (5.3.56).

The project was never taken up but it suggests that the variant could easily have dealt with the type of target that Canberra itself presented as a bomber. Incredibly, Canberra still serves the RAF today in its PR Mk.9 form, well over 50 years after its maiden flight; it has also flown with 13 other air forces. This chapter, covering Canberra only, is relatively short. Just like the Mosquito it replaced, the type was a superb aircraft and its roles were very diverse. However, this success was to create something of a problem because from the mid-1950s the RAF had the task of finding a successor. The search for a 'Canberra Replacement' was to cause quite a bit of bother and fills up a much bigger chunk of this book.

English Electric Bomber Projects – Estimated Data

Project	*Span ft in (m)*	*Length ft in (m)*	*Wing Area ft² (m²)*	*t/c %*	*All-Up-Weight lb (kg)*	*Powerplant Thrust lb (kN)*	*Max Speed / Height mph (km/h) / ft (m)*	*Weapon Load lb (kg)*
High-Altitude Bomber (1.6.45)	75 0 (22.9)	63 0 (19.2)	1,040 (96.7)	12 root 9 tip	43,800 (19,868)	1 x RB.43 12,500 (55.6)	544 (875) at 10,000 (3,048) [combat power, 28,000lb (12,701kg)]	1 x 4,000 (1,814), 6 x 1,000 (454) or mix of bombs
High-Altitude Bomber (7.45)	68 0 (20.7)	61 0 (18.6)	950 (88.4)	15 root 9 tip	39,300 (17,826)	2 x AJ.65 6,500 (28.9)	549 (883) at 10,000 (3,048) [combat power, 24,900lb (11,295kg)]	1 x 8,000 (3,629), 6 x 1,000 (454) or mix of bombs
Canberra B Mk.2 (Flown)	63 11½ (19.5)	65 6 (20.0)	960 (89.3)	12 root 9 tip	46,000 (20,866)	2 x Avon RA.3 6,500 (28.9)	570 (917) at altitude	6 x 1,000 (454), 1 x nuclear or mix of bombs

Chapter Two

Vital Bombers

Building Britain's V-Force: 1945 to 1955

Second production Vulcan B Mk.1 XA890 with the original straight leading edge and the undercarriage and airbrakes lowered. Eric Morgan Collection

My earliest recollection of aeroplanes must have been when I was about four or five. We lived in an old cottage in Broad Marston, Worcestershire, which, apart from the arrival of electricity in 1952, the telephone and some cars, had changed relatively little since the early years of the century. The peace and tranquillity of village life was now often interrupted by the roar of four Avons as a Vickers Valiant passed slowly overhead at quite low level. I think it is fair to say that the general mechanisation of British farming had hardly started in the late 1950s so the arrival of these advanced jets, as part of the immensely rapid progress in aviation under way at that time, made for a great contrast between the old and the new. A lovely memory and happy days.

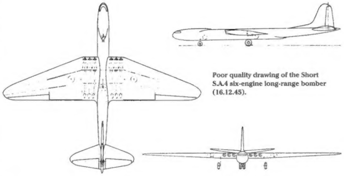
The main portion of the World War Two piston bomber fleet was to be replaced by the new Medium-Range Jet Bomber, a programme which was to give rise to the Valiant and the rest of the V-Force. A big influence was the new atomic bomb which was to become the driving force behind the development of heavy and medium bomber aircraft so, from now on, Britain's future bombers would be configured as nuclear weapon delivery systems. But what direction would the jet-powered replacements for the piston Lancaster and Lincoln take? This chapter reveals some of the background to what were to become primary elements of Britain's Nuclear Deterrent – the Valiant, Vulcan and Victor bombers. There were two main issues: how large should the new aircraft be since it was the desire of the Air Staff to have a long-range bomber, and would defensive armament be fitted?

Short S.A.4

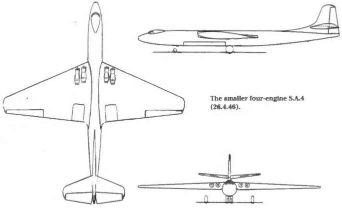
On 16th February 1945 Short Brothers at Rochester was asked by the Air Ministry to make a study to see if a 5,000 mile (8,045km) range could be attained by a jet-propelled high-speed bomber. The resulting 'Design Appreciation', finished in November and submitted on 16th December, considered the job could be done without any revolutionary changes in the methods of aircraft design. Shorts' work drew on German wartime research and the opinions of its consultant Professor Geoffrey Hill, the assumption being that the bomber was to be capable of 500mph (805km/h) at 40,000ft (12,192m). The result was an enormous machine with a four-man crew housed in a cockpit that filled the nose beyond the front wheels.

Two 30mm cannon were housed directly behind on top of the fuselage; two more were beneath the fuselage behind the wing. The main undercarriage comprised a two-wheel leg that folded into the centre of the fuselage and two more single wheels just outside the engines retracting into the wings. A large bomb bay filled most of the lower fuselage between the nose and centre gear. Six of the newly proposed Rolls-Royce AJ.65 (Avon) axial 'pure' jets were housed three per side in the inner wings. With 6,000gal (27,281lit) of fuel, take-off wing loading was 44.0lb/ft^2 (215kg/m^2), still air range 5,000 miles. Soon afterwards the company was asked to consider cutting the machine's size, the suggestion being that four AJ.65s instead of six would make for a much smaller design without, perhaps, giving too great a penalty in range or performance. This investigation, for an aircraft which had no guns, was completed on 26th April 1946 but, in regard to speed and range, Shorts felt it disappointed compared to the original.

The guns had now been taken out of the first design but some additional equipment, such as self-sealing tanks, more than counterbalanced the weight saved. Furthermore, Rolls reported a big increase in the estimated weight of its engine while Shorts had finished a more detailed study of the structural aspects for this type of aircraft so, as a result, the estimates for mainplane and tail unit weight had also risen. Much of the latter stemmed from an assumed maximum dive speed of Mach 0.95 when a figure of Mach 0.85 would give a much smaller increase. With four AJ.65s and 4,800gal (21,825lit) of fuel, range was 3,800 miles (6,114km); the undercarriage arrangement and bomb bay were unchanged and at 115,000lb (52,164kg) weight, wing loading was 42.8lb/ft^2 (209kg/m^2). The margin on the cruise speed of the six-engined aircraft came from an uncertainty as to the onset of compressibility drag, the economical cruise speed for long range being determined by this. On the four-engine layout, speed was limited by engine power and was below the speed where compressibility drag was likely to occur. Both designs were called S.A.4.



Poor quality drawing of the Short S.A.4 six-engine long-range bomber (16.12.45).



The smaller four-engine S.A.4 (26.4.46).

Shorts felt the four-engine project was still a practical proposition and that the engines could still be buried in the wings. But to put them there it would be necessary to employ a disproportionately large root chord and choose between an unnecessarily large wing area or an undesirably short span. A higher altitude, which would give a longer range, could only be achieved by increasing the span and wing area with a consequent reduction in cruising speed; all factors to be taken into account. Close study of these concepts by the Air Staff revealed there was no hope of adding defensive armament without a prohibitive penalty in weight and drag, fuelling again the strong ongoing guns/no guns debate. Nevertheless a Draft Operational Requirement was forthcoming.

By summer 1946, the Air Staff had forwarded a fairly detailed outline for a long-range bomber, the type that it really wanted. This had to be capable of delivering a 10,000lb (4,536kg) bomb load to a target 2,000nm (3,706km) from a base situated anywhere in

the world (i.e. a range of 4,000nm [7,408km]). Such an aircraft would have to attack targets well into enemy territory and, to help avoid destruction from ground or air-launched weapons, it must have a continuous cruising speed at all heights from sea level to 50,000ft (15,240m) of 575mph (925km/h) or Mach 0.875, whichever the lesser, and be capable of reaching 50,000ft with the maximum fuel/bomb load combination inside two hours from take-off. Two more companies offered designs.

Bristol Type 172

Far more advanced than the S.A.4, the Type 172 had swept wings, a swept 'butterfly' tail and four Bristol BE.10 engines buried in the wing roots and exhausting through the trailing edge (BE.10 was to evolve into Olympus). Range with the 10,000lb bomb was 5,000 miles (8,045km). A high wing loading (64.8lb/ft² compared to 44.2 and 42.8 for Shorts and Handley Page [316, 216 and 210kg/m² respectively]) led to a lower cruising altitude than the others. In October 1946 Bristol redesigned its 172 with a high wing and thinner root but retained the V-tail and wing root engines. Span was still 110ft (33.5m) but length rose to 100ft (30.5m); six 6,000lb (2,722kg) conventional bombs could be carried with 6,450gal (29,328lit) of fuel for an all-up-weight of nearly 172,000lb (78,019kg).

Handley Page HP.72A

Handley Page's HP.72 project was a heavy piston engine transport to C.15/45 abandoned around the end of 1945. HP.72A was introduced early in the new year as a general cover to screen Godfrey Lee's work on a large jet bomber, initiated after he had visited Germany immediately after the war as part of a commission to look at German research. This was ahead of any requirement. Lee's first ideas had centred on a civil trans-Atlantic transport but, after a memo from Sir Frederick Handley Page had asked the Design Department to look at a jet-propelled Lincoln replacement, he moved on to a bomber.

An alternative 90,000lb (40,824kg) layout with a front 'rider-plane' was similarly screened as HP.75A but swiftly rejected in favour of the HP.72A. This had swept wings and tip rudders but with a small swept tail so the elevators could counteract any nose-down pitching, a problem expected from high-speed compressibility or lowering the flaps at low speed. Four scaled-down AJ.65s were in the wing roots since the standard Avon was felt to be larger than was ideal. Range was 5,000 miles (8,045km), there was a tricycle undercarriage and the primary radar was H2S Mk.9 whose radome was placed below the flight deck. When presented in preliminary form in June 1946 the project was renumbered HP.80. Despite weaknesses, the 172 and HP.72A/HP.80 were remarkable for their day and show how some British companies were ready to experiment with new aerodynamic shapes.

RAE Farnborough reported in July 1946 that the estimated structure weights of all three projects were probably optimistic, the two high sweepback designs being difficult to assess in this respect since the effect on structure weight from such a configuration was yet to be explored. Both had high top speeds and any estimate would have to depend on very scanty data of air load distributions for swept wings at high Mach numbers. Each design's cruise speed, particularly the Bristol 172, was very near that for compressibility drag rise if not beyond it, and extensive tunnel testing would be needed to minimise the problem. For the 172, however, the Farnborough high-speed tunnel was not capable of exploring the speeds needed. Both Bristol and Handley Page had thickened the wings of their projects at the root, a step considered inadvisable aerodynamically since it was in this region that the favourable effects of sweepback were least applicable.

At first, the Air Staff had only intended to issue a long-range bomber requirement, but by December 1946 it was realised such an aircraft would be very expensive and financial stringency made it unlikely that any but a few squadrons could be equipped with it. The severe requirement (OR.230) would need an exceedingly heavy load of fuel and some studies suggested final all-up-weight could reach 200,000lb (90,720kg). With swept wings, this represented too great an advance in design to be entertained at present while any project would also probably need half-scale flying models. As the majority of targets could no doubt be reached by an aircraft having about 75% of the original range, requirements were prepared for an advanced medium-range bomber, a step that crystallised into OR.229 and Specification B.35/46. However, this too would be difficult to meet since it would still need swept-back wings and other, as yet untried, features, so an Interim Bomber was also introduced as a back-up.

Investigation had now shown that it did not pay to have defensive armament if a speed of about 575mph (925km/h) could be reached at high level. On the other hand, if defensive armament was introduced, speed and altitude would be lost and the resulting aircraft would likely be no more than an improved Boeing B-29 with reciprocating engines. It was also thought impractical to devise adequate armour to counter new fighters firing controlled rockets at a range of 2 to 4 miles (3.2 to 6.4km). The requirement visualised a high-speed, high-altitude, unarmed bomber built around the atomic bomb; weight was critical.

Short B.14/46

By November 1946, the four-engine S.A.4 had been chosen as the Interim insurance bomber. Specification B.14/46 (possibly reserved at the start for the long-range OR.230 bomber) and OR.239 were prepared around it. Cruise speed between 35,000 and 45,000ft (10,668 to 13,716m) was to be 450mph (724km/h) and, with a 10,000lb (4,536kg) bomb load, radius of action was 1,500nm (2,780km). Maximum load was 20,000lb (9,072kg).

At the end of January 1947, David Keith-Lucas of Shorts finished a study for a propeller-turbine (turboprop) S.A.4 capable of 500mph (805km/h) at 40,000ft (12,192m) at an all-up-weight of about 110,000lb (49,896kg). This showed that eight Bristol Proteus engines were needed in four coupled pairs instead of the four AJ.65s and the effects of this were not good. Total weight for eight Proteus against four AJ.65s was 24,800lb (11,249kg) against 7,800lb (3,538kg) which, despite a reduced fuel volume, meant an increase in all-up-weight of over 13,000lb (5,897kg) and a cut in range of well over 1,000 miles (1,609km) compared to a jet-powered type of similar structure, equipment and bomb load. The results were checked using published figures for the Armstrong Siddeley Python turboprop which showed to rather less advantage than the Proteus. This work confirmed Keith-Lucas's July 1945 findings when a pure jet, propeller turbine, ducted fan and mixed pure jet/propeller turbine had all been reviewed. Four jets offered a much neater layout.

Agreement for ordering two S.A.4s was reached in late February 1947 at which point it was planned to house the four AJ.65s side-by-side in two underwing nacelles. However, in mid-February 1949, after tunnel tests at RAE Farnborough, Keith-Lucas confirmed that two engines in a single vertical nacelle above and below each wing had been adopted instead of the previous arrangement or an alternative four single underwing nacelles. Rolls experience on a design with twin engines mounted side by side had indicated that the aerodynamic forces on the cowl were very large and needed a heavy structure. Engines arranged horizontally in a nacelle suspended below the wing by a slim faired strut were also suggested (and favoured at RAE), but Shorts rejected this

because it presented several structural problems and would be difficult to accommodate without extensive redesign of the wing. Prototype construction had just begun.

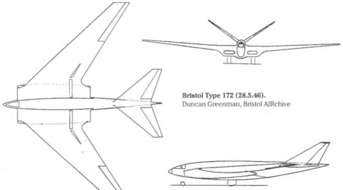
B.35/46
(and Operational Requirement OR.229)

Issued on 7th January 1947, Specification B.35/46 called for a bomber to hit a target up to 1,500nm (2,778km) away at a continuous 500 knots (576mph/926km/h) cruise at 45,000 to 50,000ft (13,716 to 15,240m). Maximum speed must be as high as possible but exceeding the cruise speed was not essential. Still air range with a 10,000lb bomb load had to be 3,350nm (6,208km) with the cruise ceiling of 50,000ft reached within two and a half hours from take-off. Maximum performance was the ultimate aim and was not to be sacrificed unduly for ease of maintenance, while flight had to be possible in all weather conditions.

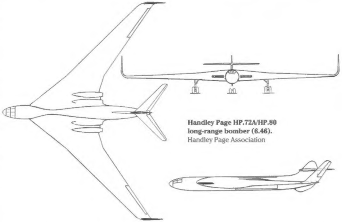
All-up-weight was not to exceed 100,000lb (45,360kg) and the 20,000lb (9,072kg) bomb load included the following alternatives: two 10,000lb concrete-piercing, two 10,000lb HC (High Capacity), four 5,000lb (2,268kg) HC, twenty 1,000lb (454kg) MC (Medium Capacity), twenty 1,000lb incendiary & fragmentation clusters or one Special (nuclear) gravity bomb (to OR.1001 – later called Blue Danube). No defensive armament was to be fitted, only warning devices and the crew comprised two pilots, two navigator/bomb aimer/radar operators and one wireless/warning and protective device operator. This requirement was put out to tender in January 1947 and six submissions were forthcoming.

Armstrong Whitworth AW.56

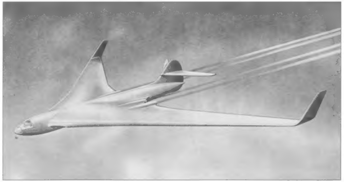
This design dispensed with a tailplane since Armstrong Whitworth (AWA) felt the various problems presented by sweptback wings were easier to solve with a tailless aircraft. In addition, little was known about the behaviour of a tailplane in the downwash of a heavily swept wing working at high Mach numbers. By careful manufacture and the provision of boundary layer suction, AWA was confident that it was possible to maintain laminar flow over the first 30% of the wing chord while suction further reduced shock stall effects at high speed and improved low-speed stalling characteristics; range was dependent on a smooth laminar airflow over the wing since it reduced drag. Wing suction



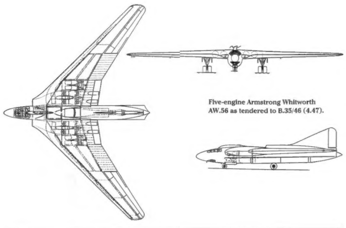
Bristol Type 172 (28.5.46).
Duncan Greenman, Bristol AIRchive



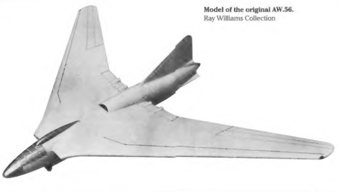
Handley Page HP.72A/HP.80 long-range bomber (6.46).
Handley Page Association



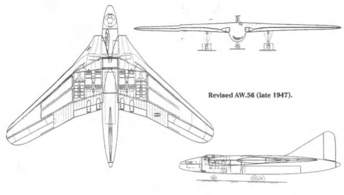
Artist's impression of the HP.72A/HP.80.
Handley Page Association



Five-engine Armstrong Whitworth AW.56 as tendered to B.35/46 (4.47).



Model of the original AW.56.
Ray Williams Collection



Revised AW.56 (late 1947).

was to be employed at all speeds and was achieved through a series of slots located at .15 chord over 77% of the span; it also gave a high critical Mach number. Continuous suction at high engine speeds was maintained by an auxiliary axial flow fan driven by the engines. Leading-edge slats were rejected because they damaged the smooth airflow and increased drag; semi-Fowler type flaps were placed well forward of the main chord.

Using an orthodox two-spar structure on large-span swept wings made it difficult to obtain the aeroelastic requirements so the AW.56 utilised box spar construction combined with cellular-type wing covering which testing had proved to be highly efficient and almost twice as stiff as the usual two-spar system. Consequently, practically all of the wing ribbing was eliminated which simplified production by allowing plenty of prefabrication prior to assembly. The structure comprised a metal sandwich of a fairly thick outer skin reinforced by a second corrugated skin and a third thin inner skin riveted to the bottom of the corrugations to provide strength and stiffness. The corrugations supported the outer skin at very close intervals thus providing and maintaining the smooth accurate wing surface required for laminar flow, a method of assembly exactly the same as the then nearly complete AW.52 research aircraft to E.9/44. Experiments on this type of skin had shown that buckling did not occur until just before the ultimate factor.

AW.52 experience had revealed that one of the most difficult problems in the design of high-speed tailless aircraft, or indeed any sweptback wing, was the provision of adequate flexural and torsional stiffness to prevent aileron reversal and wing-aileron flutter. The bending stiffness of a swept wing was vitally important since pure bending distortions produced changes in incidence, something that did not occur in a normal unswept wing.

Longitudinal and lateral control were achieved using two surfaces in tandem on each outer wing called the 'corrector' and 'controller'. Like the AW.52, the corrector was the forward surface and its function, under power operation, was to provide the pilot with a course-trimming device capable of counteracting major changes of longitudinal trim such as occurred when the landing flaps were lowered. The controller acted as an elevator and aileron, and was hinged behind the corrector. A tricycle undercarriage had main wheels of long vertical travel to allow the aircraft to glide unchecked onto the ground, a capability thought to be helpful in poor visibility. Investigations showed AW.56

was controllable and stable in all conditions and about all axes but the control surfaces were provided with pressure-sealed balances, again tried on the AW.52, to give the pilot a measure of manual control if needed.

Four Avons were mounted in the wing roots and a fifth in the fuselage rear with its own intake on the upper fuselage. At 36,000ft (10,973m) and 90,000lb (40,824kg) weight, top speed was estimated to be 640mph (1,030km/h) Mach 0.97. Fully laden, sea level rate of climb was 4,180ft/min (1,274m/min). A normal flight plan would comprise a climb to 40,000ft (12,192m), cruise for 105 minutes and then further climb to 50,000ft (15,240m), this height being reached after 2.5 hours flying. The brochure stated that maximum cruise speed at 50,000ft and 80,000lb (36,288kg) weight would be 580mph (933km/h) Mach 0.88 without compressibility drag, 545mph (877km/h) Mach 0.825 with compressibility drag. However an Air Staff document gave 501mph (806km/h) at 50,000ft, which suggests they had doubts.

All bomb loads (nuclear or small or large conventional) were held in the fuselage; the bomb bay doors divided transversely in the centre, the sections sliding fore and aft to prevent any serious effect on speed and trim. Internal fuel, in fuselage and wing tanks, totalled 5,620gal (25,554lit) and maximum wing loading was 43.3lb/ft² (211kg/m²); range was 3,350nm (6,204kg) with 10,000lb (4,536kg) of bombs. Completion of detail design from ITP was predicted to take 100 weeks with first flight taking another 20 weeks. MetroVick F.9s could substitute the Avons without major changes and, for two reasons, they offered a considerable reduction in the fuel required for the specified range. First, they had a lower fuel consumption when cruising; second, their greater thrust allowed a direct climb to 50,000ft with no intermediate cruise. The fuel saving was about 6,700lb (3,039kg) for a take-off weight of 106,000lb (48,082kg).

After the Tender Design Conference, a revised AW.56 was proposed to meet the Air Staff's relaxed intermediate bomber requirements (below) which used a new Rolls-Royce 7,500lb (33.3kN) 'Avon Replacement' bypass engine. This was the RB.77 and was Rolls' first bypass engine prior to the RB.80 Conway. RB.77 was physically interchangeable with the Avon and was expected eventually to supply 8,000lb (35.6kN) thrust as the BJ.80 (bypass jet, 8,000lb). Four units were fitted permitting deletion of the tail motor and its intake for a more streamlined shape. The pilot now had a fighter-type canopy offset to port with the rest of the crew hidden in the fuselage and, overall, the aircraft was a touch smaller. Climb rate at ground level with RB.77s was 4,475ft/min (1,364m/min), fuel capacity 4,630gal (21,052lit). An alternative had just the four Avons for a maximum weight of 97,200lb (44,090kg) and cruise at 547mph (880km/h).

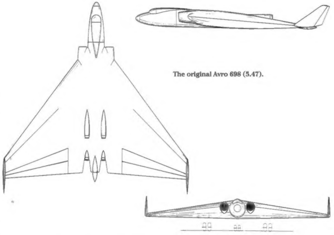
Avro 698

In 1947 the new problems faced by the designers of advanced aircraft were many. In order to fly economically there must be the minimum possible drag and in order to keep drag down at speeds approaching the speed of sound (as these machines were) it was necessary to sweep the wings back at a very pronounced angle to the fuselage. In addition, wing thickness had to be kept as low as possible; that is to say, whatever the wing chord was at any particular point along its span, the thickness should be kept to 10% or even less. Furthermore, if one wanted to fly at a high true air speed and go as far as possible with an economical fuel load, it was known that you must go as high as possible, where the air was less dense.

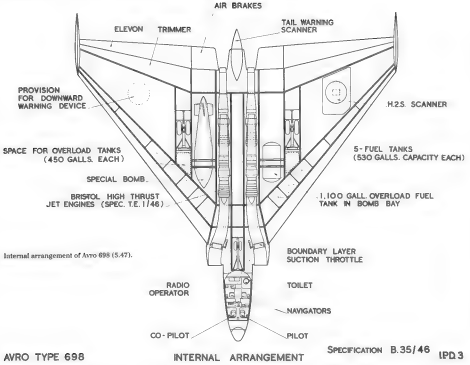
Unfortunately, the speed of sound drops with increasing altitude and so, as you design to fly higher, you must not only take the steps mentioned already, but in addition keep the angle between the wing and the flight path (known in 1947 as the angle of incidence, more recently, the angle of attack) low otherwise the drag would rise very rapidly. In order to keep the angle of incidence low it was necessary to keep the wing loading low, or in other words for a given weight of aircraft the wing area must be larger than had previously been the case. Another factor was that on a long-range bomber, or commercial aircraft, if you wanted to fly long distances you utilised wings of high aspect ratio; that is, the span was large relative to the chord, the ratio varying from perhaps 9 up to 14. This was necessary to keep down induced drag (the drag penalty from wing lift).

This broad picture was what the designer of a large, load-carrying long-range aircraft was faced with. If he wished to fly at speeds comparable with the speed of sound he had, at one and the same time, to sweep the wings back, make them thinner, increase the area and keep up the span. This posed very great structural problems. (The above section is based on text from an Avro report *The Case for the Delta*, written by S Davis in April 1951).

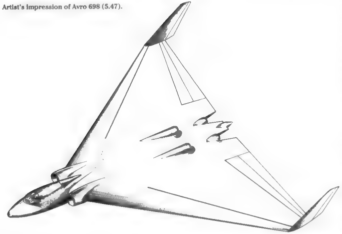
Avro realised that B.35/46 could not be met by present types of aeroplane since the high speeds called for the use of all known aerodynamic improvements, much new research into aerodynamics and the development of much more powerful jet engines than those currently available. The 500 knot (927km/h) requirement between 36,000 and 50,000ft (10,973 and 15,240m), when the speed of sound was 574 knots (661mph/1,064km/h), implied that the critical Mach number must be greater than 0.872; this made a thin wing of high-speed section and large sweepback a necessity. Preliminary investigations using all available British and German reports com-



The original Avro 698 (5.47).



Internal arrangement of Avro 698 (5.47).



Artist's impression of Avro 698 (5.47).

pared a conventional swept wing/swept tail design, a tailless swept wing aircraft and a delta wing and concluded that only the delta could meet the speed, range, load and gross weight limits laid down. It appeared impossible to meet B.35/46 with a conventional arrangement at any gross weight while the tailless machine weighed in at 137,500lb (62,370kg), had a span of 138ft (42.1m) and wing area of 4,540ft² (422.2m²).

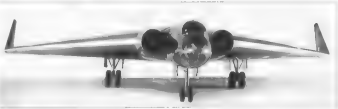
Avro felt the delta provided a neat solution to B.35/46. Whilst admitting that it was still largely an unknown quantity, the company was confident that, both aerodynamically and structurally, it would be less difficult to develop the delta wing than either of the other options. Control and stability were no more difficult and structurally there were enormous advantages since it was simple in form and, even with a low t/c, it was inherently adapted to take care of both flexural and torsional loadings through its great depth of wing section. In addition, it automatically provided a great internal volume for powerplant, equipment, fuel and bombs. At its centre the delta's wing was 7ft 9½in (237.5cm) deep and Avro noted that the delta would give the lowest possible structure weight of any form of aeroplane. In comparison, the piston Avro Lincoln had a span of 120ft (36.6m) as against the 698's 91ft 6in (27.9m), yet at the centreline the Lincoln's wing depth was just 2ft 10½in (87.6cm).

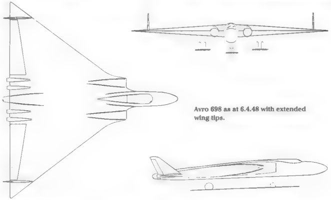
The only excrescence were the air intakes, the jet pipes and an extension of the nose for the crew nacelle. Two pairs of stacked superimposed engines, expected to be Bristol 'High Thrust Jet Engines to TE.1/46' (later the BE.10 Olympus), were completely buried in the wing very close to the centreline so that the offset thrust in the event of an engine failure was very small and easily controlled. The top 'forward' pair exhausted above the centre wing upper surface, the lower 'rear' pair through a cut-back section of the trailing edge and they were fed by two big circular pitot intakes. All the fuel was carried in ten tanks in the leading edge. Thanks to the low wing loading, just 29.7lb/ft² (145kg/m²), there were no landing flaps.

Longitudinal control and trimming were effected by a trimming 'controller' and by differentially operated elevons at the wing trailing edge. Wing tip fins and rudders gave directional control but it was thought these might be deleted after further research. High-speed tunnel evidence indicated slightly better stability characteristics at high speed for the delta layout but the effects of the tip fins on these high-speed characteristics were unknown. Boundary layer suction was provided over the span covered by the ailerons via a large valve in the air intake just ahead of the point where it bifurcated, the valve only operating during take-off and landing.

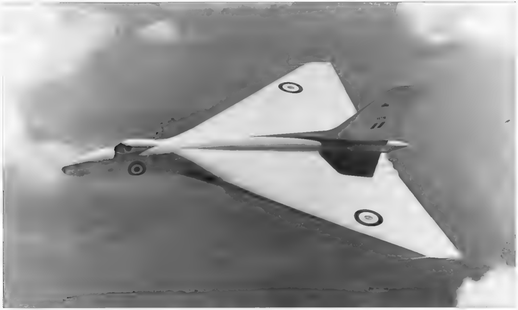
Since there was no fuselage as such, the bomb bay was split in two either side of the engines each side could take eight 1,000lb (454kg) conventional bombs or, when in atomic 'mode', the port bay took the nuclear store while more fuel was housed in the starboard bay, although each compartment was capable of carrying two of the large 'special bombs'. It was proposed to suppress all external aerials and the H2S scanner, mounted inside the port wing, had a suitable area of the bottom plating made in timber construction to give the necessary visual angles. The tricycle undercarriage had its main gears outboard of the weapons bay. Avro stated that the aircraft would be simpler to build than

Model of the Avro 698 showing internal detail.
Avro Heritage Centre





Avro 698 as at 6.4.48 with extended wing tips.



existing types bar the wing leading edge up to 25% of the chord which would have to be laminar flow construction requiring considerably more care in manufacture than had been customary in the past. This point, of course, would apply to all future high-speed aeroplanes and the laminar flow construction was based on the lines developed by Armstrong Whitworth.

At 50,000ft (15,240m) maximum cruise speed was 576mph (927km/h), at 20,000ft (6,096m) it increased to 632mph (1,017km/h); rate of climb at sea level was 5,900ft/min (1,798m/min) and the fuel totalled 5,030gal (22,871lit). The 698 met all the performance requirements except that the altitude over the target would be 49,000ft (14,935m) instead of 50,000ft (15,240m) and gross weight rose to 104,000lb (47,174kg), not 100,000lb (45,360kg). If the Bristol engines were not ready for the prototype, it could be flown with Rolls-Royce Avons or MetroVick F.9s (later the Armstrong Siddeley Sapphire) although these would reduce both mean altitude and cruise speed. Design completion from ITP would need 156 weeks, 208 weeks were quoted from ITP to first flight. Finally, Avro noted that at 20% overload, the 698 could meet the range and bomb load requirements of the long-range OR.230. The brochure was dated May 1947.

English Electric B.35/46

This relatively conservative project, dated 7th April 1947, makes a good contrast to the Avro 698; something of a surprise when one considers the radical designs Petter had produced at both Westland and English Electric (EE). It was treated as an attempt to provide a high cruise altitude and low all-up-weight at the expense of equipment and cruise speed and was designed to meet both medium and long-range requirements with the same airframe but with increased internal and jettisonable fuel tanks. After careful consideration of seventeen alternative combinations of aerodynamic and engine layouts, EE stated that its project met both OR.229 and OR.230 in the great majority of respects; the only exception was performance. Whilst appreciating the need for the highest possible cruise speed to avoid interception, the company considered that the difference in the layout required between 450 and 500 knots (518/576mph, 834/927km/h) was of a revolutionary character.

With present knowledge, it was not a practical proposition to design a 100,000lb (45,360kg) class aeroplane having a cruising speed of 500 knots; EE believed this must be approached in stages and hoped that the B.3/45 (Canberra) would contribute much to this end. The high Mach number was the

The first Avro 698 Vulcan prototype VX770.
Avro Heritage Centre

biggest unknown and, until satisfactory flying qualities were obtained in level flight by at least a fighter-class design, without the limits of size and range, EE felt it would be most imprudent to promise the full combination desired. In addition, it was unlikely that those fighters in service in the next eight years would have any margin of speed and ceiling to intercept and outmanoeuvre this proposal flying at 450 knots and 50,000ft (15,240m). The company was hopeful that a speed of 475 knots (547mph/880km/h) would be possible after high-speed tunnel tests using information from work conducted by Gothert in Germany on improved wing sections, but a more conservative 450 knots (518mph/834km/h) was used for the brochure performance estimates.

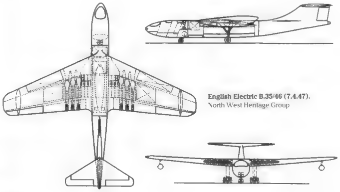
To back this up, the specified cruising altitude had been exceeded while the aircraft's size was kept within reasonable limits. The latter was achieved four ways. Firstly, evidence from the USA supported the view that structure weight could be of low order provided the limiting dive speed was strictly controlled. The speed proposed was 403mph (648km/h) EAS which meant considerable restrictions both in level and diving flight at

low altitude, but this ceased to have an effect over 27,000ft (8,230m). Secondly, new and more fuel-efficient engines were expected which reduced the volume of fuel to be carried. Thirdly, the engines and undercarriage were completely buried in the wing and by using six engines, and keeping protuberances to a minimum, this provided a drag reduction which reduced the coefficient by 10% from the B.3/45. Finally, every effort was made to keep down equipment weight. EE had discovered that 1.5lb (0.7kg) of fuel was burnt in each sortie for each pound (0.45kg) of equipment carried so detailed control was essential.

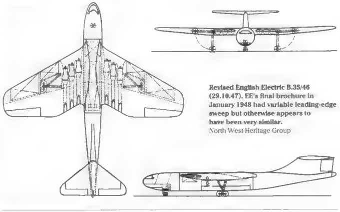
The wings were of two-spar construction with the three-wheel main gears and three engines per side mounted between the spars. The outer wings contained large integral fuel tanks and all control surfaces were power operated. To achieve the long-range OR.230, the standard machine was overloaded with drop tanks and additional internal fuel, yet at 96,310lb (43,686kg) its weight was still under OR.229's limits. In the medium-range case, capacity was 3,600gal (16,357lit), for long range 5,000gal (22,718lit); equivalent ranges for cruise at 518mph (833km/h) were 3,400nm (6,297km) and 4,400nm (8,149km). Top level speed was 593mph (954km/h) at 24,000ft (7,315m); service ceiling at 90,000lb (40,824kg) weight was 50,000ft (15,240m), at 50,000lb (22,680kg) it was 62,000ft (18,898m); maximum rates of climb were 5,600ft/min and 10,300ft/min (1,709m/min and 3,140m/min) respectively. Full wing loading was 42lb/ft² (205kg/m²).

The Mk.9 H2S gave the biggest installation job and profoundly affected the aircraft's layout after considering various positions, it was placed at the rear of the bomb bay. Six axial jets of 4,850lb (21.6kN) thrust were specified, either Napier E.131 or Armstrong Siddeley, mounted in the wing roots and arranged with the compressors partly projecting through the front spar. A maiden flight was predicted at 152 weeks from ITP. Further investigations demonstrated that it was possible to carry two 10,000lb (4,536kg) MC bombs situated one above the other with the bomb bay doors partly open and the lower store projecting outside the fuselage contour for about a third of its width.

On request this project was revised, in a brochure dated 29th October 1947, to accommodate Avon or F.9 (Sapphire) engines which were already well on the way to development. The use of four Avons or F.9s was possible for the range only if a reduced cruising speed of 489mph (787km/h) and a large altitude reduction were accepted; EE felt this



English Electric B.35/46 (7.4.47).
North West Heritage Group



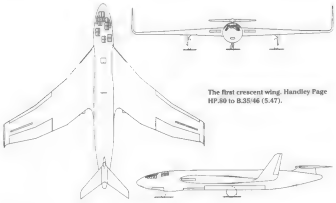
Revised English Electric B.35/46 (29.10.47). EE's final brochure in January 1948 had variable leading-edge sweep but otherwise appears to have been very similar.
North West Heritage Group

aeroplane was underpowered. Fitting six units pushed the performance up to the specified figures and slightly improved on the original design with cruise now at 547mph (880km/h). Sweep angle at one-quarter chord had been increased from 20° to 30° but all-up-weight rose to 111,150lb (50,418kg) with Avons or 111,350lb (50,508kg) with F.9s. Both offered a range of 3,400nm (6,297km) and a height of 51,000ft (15,549m) over the target. Internal fuel totalled 5,850gal (26,580lit) and the H2S was moved to the nose.

Handley Page HP.80

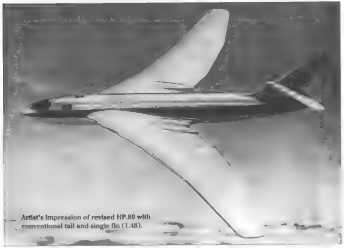
The original HP.72A/HP.80 was revised for B.35/46, the main external differences being a very short stub fin and the introduction of a second kink in the wing to give what HP called the 'crescent' wing. HP.72A's wing had a small single kink outboard of the engines with the remainder tapering to the tip fins. The crescent had evolved from extensive wind tunnel research and the relationship between sweepback and t/c ratio, varied progressively along the wing, was designed to give a high and approximately constant critical Mach number along the span with freedom from shock wave formation (so delaying drag rise). It gave a low structure weight and avoided the tip stalling and loss of longitudinal stability inherent in the retention of high sweep at the tips.

HP stated that without sweepback the wings would be so thin that the structure weight would be prohibitive and the undercarriage, engines and fuel could not be housed in them. The crescent wing had its semi-span divided into three near-equal parts, the quarter chord lines of which were swept back at 48.25°, 37.5° and 26.75° to give



The first crescent wing. Handley Page HP.80 to B.35/46 (5.47).

Artist's impression of the tip-finned HP.80.



Artist's impression of revised HP.80 with conventional tail and single fin (1.48).

the greatest sweepback at the structurally important centre section and least at the tips where the section was thinnest. Thin wings with small sweepback, or large uniform sweepback, would either be excessively heavy or have poor stalling properties.

The wing had flaps and leading-edge slats over the outer 50% of its semi-span in conjunction with rear slots at 60% of the chord. This combination of slots controlled the boundary layer on the outer wing so that flow breakdown, normally associated with large sweepback, was delayed until the general stalling angle was reached. On a straight wing of equivalent sweepback, leading-edge and rear slots were found to be inadequate to prevent premature tip stalling; only by the combination of slots and a crescent planform that satisfactory stalling behaviour was obtained.

All flying controls were fully power operated with complete duplication and no mechanical feedback or mass balancing. The tip fins and rudders were made structurally integral with the wings, the junction being carefully faired. Tests of the crescent planform with and without tip fins showed that the fins offered a reduction in drag without detriment to the tip stalling properties. Wing structure consisted of a single spar with concentrated light alloy flanges, a torque box with front and rear webs and closely spaced ribs. Forward of the spar the skin was of sheet sandwich construction whilst aft single skinning was used, a method adopted to ensure the best possible surface for laminar flow. There were no spanwise stringers.

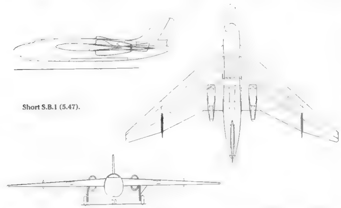
A small slab tailplane, rotatable about a spanwise axis to provide variable incidence (all-moving), gave additional damping in pitch and provided longitudinal trimming at cruising and climbing speed without recourse to trimming the elevons. Trimming by elevon alone distorted both chordwise and spanwise loading and thus impaired the retention of laminar flow over the outer wing. The tail also made the problem of balancing the nose-down moments during flap operation much easier and was a powerful control to deal with large changes of longitudinal trim near the transonic region. There was a tricycle undercarriage and, like all B.35/46 projects, the crew cabin was jettisonable as a unit. A shallow streamlined 'blister' in the lower fuselage just rearward of the cabin housed the H2S navigation scanner. Much of the fuselage was built conventionally with alloy hoop frames and stringers but some of the skinning was made of resin-impregnated glass fibre sandwich with onozote filling.

Four MetroVick F.9 axial engines were placed two per side adjacent to the fuselage

Three views of the prototype Victor WB771 in overall silver finish.

and mounted between strong tail ribs carried from the wing spar. The intakes were in the leading edge and the pipes faired into the trailing edge and, in the case of the inboard engines, also into the wing root fillet. Rolls AJ.65s would become an alternative when they had been developed sufficiently to give the same thrust and specific fuel consumption. By the time the brochure was submitted, the design of a one-third scale glider to check low-speed flight characteristics had commenced (noted in pencil on an MoS copy as 'a bit premature').

Sea level rate of climb at maximum all-up weight was 6,200ft/min (1,890m/min); with a 10,000lb (4,536kg) bomb still air range was 3,350nm (6,208km). Normal fuel tankage was 3,092gal (14,059lit) with another 1,240gal (5,638lit) available in auxiliary tanks. Full load wing loading was 47.5lb/ft² (232kg/m²). A 'flying shell' prototype was expected to fly in March 1952, and a fully equipped machine in September 1952, based on a programme start date of 1st October 1947.



Short S.B.1 (5.47).

Short S.B.1

Shorts considered this tailless aircraft to be the optimum for B.35/46 and it incorporated much experience gained with the B.14/46 'Interim Bomber'; in many ways it was a direct development. Nevertheless it had been found impossible to meet the range and altitude requirements with an aircraft of this size unless the equipment weight could be substantially reduced; a larger machine with six or more engines would be necessary to meet the performance in full and this would be well over the required weight. Shorts' weight estimates owed much to the detailed structural investigations made for the B.14/46.

Fuselage arrangement and bomb bay were very similar to B.14/46 with the jettisonable forward section, including the pressure cabin and H2S scanner, practically identical. But, whereas the conventional straight wing interim type could cruise at 500mph (805km/h), the sweptback S.B.1 could cruise at 575mph (925km/h). At 50,000ft (15,240m) this gave a Mach number of 0.87 which necessitated a large sweep angle of about 40° to delay the onset of compressibility. With so large a sweep, a tailless design immediately became practical and, for a number of reasons, was preferred to a conventional tail. This flying wing with a central fin was intended to remove the parasitic drag of a normal tail.

Preliminary schemes had been prepared both with and without tails. Among the arguments for not having a tail were:

1. The tailless type would have a small advantage in structural simplicity, weight and drag over that with a tail.
2. When a tail was fitted it was necessary to ensure that it still provided good control up to and beyond the speed at which the wing became shock stalled. A large sweep angle was therefore required on the tailplane which would result in a serious loss of elevator effectiveness.
3. On a swept wing it was quite easy to put the flaps where flap deflection caused little or no change of pitching moment on the wing and therefore no change of trim on a tailless aircraft. Once a tail was introduced the balance was upset by the downwash on the tail and could only be restored by moving the flaps a long way aft of the wing or by extending them to the wing tips (S.B.1 had split flaps).
4. On this particular design it was desirable to fit at least one engine and a rear warning scanner in the end of the fuselage; a tail would create structural complications.

Longitudinal and lateral control and the prevention of tip stalling were the next problems. The control problem was complicated not only by the high Mach number but also by the aeroelastic effects which were particularly troublesome on a swept wing. It had recently become increasingly evident that on conventional high-speed aircraft it was essential to provide adjustment of the tailplane incidence, otherwise violent variations in stability might occur with increasing speed due to torsional deflection of the tailplane. In fact, the tailplane incidence had to be so adjusted that the elevator setting was very nearly neutral at high speed. This problem applied even more forcibly to a tailless design because the torsional rigidity of a wing was obviously likely to be less than that of a tailplane.

One solution was to fit a small trimming tail but this introduced a weight penalty and other complications. A more direct solution was to fit the equivalent of an all-moving tail, namely all-moving wing tips or 'controllers' so designed that as the wing bent, they were able to twist just sufficiently to preserve the correct incidence. This had been advocated by Professor Geoffrey Hill and flown on his Pterodactyl aircraft in the 1930s. Such wing tips provided control, freedom from tip stalling and the avoidance of aileron reversal. Good control could be obtained up to higher Mach numbers than was the case with conventional surfaces because the tips operated at a lower incidence than the rest of the wing and therefore shock stalled later. Extended over the outer third of the span they could be moved together for elevator control and differentially for aileron control. It was essential that they were power operated.

Shorts noted that the simplicity of the scheme had much to recommend it over any other system yet devised. Structural factors were an obvious objection but the company felt that the problem was similar to the wing fold on quite a small naval aircraft. This feature was later termed the 'aero-isoclinic' wing. The fin and rudder were mounted on the fuselage but small auxiliary fins were also placed just inboard of the controllers to prevent cross flow at the controller hinge, further help to prevent tip stalling and to increase directional stability.

Five AJ.65 Avons powered the S.B.1; a six-engined design was rejected because the all-up-weight was too high. It had been hoped that three engines could be mounted in the rear fuselage but this was found to be impractical, so one unit only was housed in the fuselage with two in each wing mounted in pairs one above the other aft of the rear spar. This arrangement offered low frontal area and was unlikely to affect critical Mach number to any extent. The difficulty would be to provide satisfactory intake orifices, a problem inherent in wing engines on a swept wing.

At 115,000lb (52,164kg) all-up-weight, sea level combat speed was 628mph (1,010km/h) and 595mph (957km/h) at 40,000ft (12,192m); equivalent cruise speeds were 544mph and 578mph (875km/h and 930km/h). A maximum 638mph (1,027km/h) was possible at 12,000ft (3,658m). It was estimated that the specified cruise speed in B.35/46 could just be achieved without any compressibility drag rise but it required maximum cruising thrust from all engines. Range was 2,730nm (5,056km) if the bombs were carried all the way, 2,930nm (5,426km) if they were dropped half way. Sea level rate of climb was 3,740ft/min (1,140m/min). Internal fuel totalled 4,720gal (21,461lit) and take-off wing loading was 48.2lb/ft^2 (235kg/m^2); service ceiling was 47,500ft (14,478m).

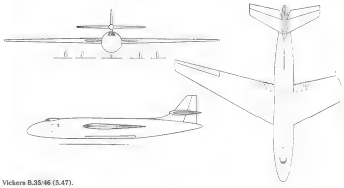
Vickers B.35/46

Vickers' first drawing to B.35/46 was dated 21st February 1947. When the project was tendered in May it was similar but the long slim fuselage was shorter and more tubby, two long bomb bays had been merged into one and the crew canopy was no longer faired into the fuselage contours. It was described by the company as a practical aeroplane based on relatively orthodox lines which did not embody highly advanced aerodynamic features necessitating years of research work and the construction of flying models. It had a straight-taper wing with a moderate 25° of sweepback and six wing root Napier E.131 engines. Alternative powerplants were the Avon, MetroVick F.9 and Armstrong Siddeley AS.45 while the four-legged main undercarriage had previously been seen on the company's piston engine Windsor. Wing loading was 49lb/ft^2 (239kg/m^2), sea level rate of climb 4,000ft/min (1,219m/min), cruise at 50,000ft 530mph (853km/h) and range 3,350nm (6,208km). Internal fuel totalled 4,875gal (22,166lit).

Like EE, Vickers chose a lower cruise speed in order to obtain more height over the target. Maximum speed was 591mph (951km/h) at 20,000ft. A period of 178 weeks was predicted from receipt of order to completion of drawings, and 195 weeks to the first flight, so, from a late 1947 go-ahead, flight could be expected in September 1951 with production deliveries commencing early in 1953. The importance of this timetable had been emphasised by both the Air Ministry and MoS and, therefore, was allowed to influence the whole design.

Following the Tender Conference, Vickers became the third company to submit a revised design to incorporate some changes and relaxed requirements suggested by the Air Staff (detailed later). As modified, four Avons or F.9 Sapphires (the latter following a verbal request from DMARD [J E Serby] to fit them) replaced the six Napier units. The aircraft's appearance was closer to the eventual Valiant bar overall size, a narrow cockpit and a bullet tail fairing, but the fundamental concept of the original design and the programme timescale were retained.

The wing root was swept 37°, the outer section 20° with a curved leading edge blending the two sections together. Increased sweep at the root delayed the onset of compressibility while the satisfactory stalling and handling properties associated with low sweepback were retained by the outer plane. It was generally recognised that ineffectiveness of the sweepback at the root caused only half the theoretical compressibility gain to be obtained in practice; with this planform the full theoretical gain should be obtainable near the tip. Thus the proposed wing was as effective in delaying compressibility as a straight-tapered wing swept 29°.



Vickers B.35/46 (5.47).
Eric Morgan Collection

These changes increased 'over target' cruise speed with four Sapphires to 570mph (917km/h) at 45,000ft (13,716m); range was 3,350nm (6,208km) and ceiling 51,000ft (15,550m). Sea level climb rate was 5,230ft/min (1,594m/min); for the Avons 3,320ft/min (1,012m/min). At about 85,000lb (38,556kg) weight, top speed with Sapphires was 599mph (964km/h) at 30,000ft (9,144m), with Avons 584mph (940km/h). The concession to reduce maximum bomb load to one 10,000lb, two 6,000lb or eighteen 1,000lb permitted a smaller fuselage diameter of 11ft 3in (3.4m), down from 13ft (4m), and saved 5,000lb (2,268kg) in weight. A tandem-wheel tricycle undercarriage was now used.

Further development was possible by fitting the 7,500lb (33.3kN) 'Avon Replacement' RB.77 bypass engine. By adding 1,730gal (7,866lit) of internal fuel for an all-up-weight of 124,600lb (56,519kg), Vickers predicted that the long-range OR.230 demands could be met with a cruise speed of 553mph (890km/h) at 48,500ft (14,783m) over the target. It was emphasised, however, that no features of the basic B.35/46 design had been influenced by this version; in all respects the design offered was the optimum for the medium-range requirement.

RAE Farnborough commented on each project. No design was considered entirely satisfactory, but all except Vickers and EE reached the specified cruising speed, this pair opting for a lower figure in order to obtain more height over the target. It was clear there were important gaps in the knowledge of stability

Impression of the revised Vickers project to the relaxed B.35/46 requirement (late 1947).

and control at high speeds which made it impossible to declare that a particular design would be satisfactory without extensive tunnel testing. It was for instance not possible to say whether or not a tailplane was necessary. In present form the HP.80 was considered the best but the Avro Delta had several potential advantages which could be exploited with some redesign. Limited experience with delta wings gave doubts as to what critical Mach number might be achieved.

The Shorts isoclinic wing was likely to remain effective above Mach 0.90 but needed a great deal of research before a satisfactory scheme could be developed. AWA's system would also need work for control to be satisfactory at high speeds; this machine's best cruise speed was likely to be its critical Mach number of 0.87. The Vickers project was expected to have a maximum usable cruising speed of Mach 0.79 (520mph 837km/h), not the Mach 0.84 (553mph/890km/h) quoted by the company, and RAE felt the cruising height and range must be reduced in order to reach this speed.

EE's and Vickers' designs were described as semi-conventional projects; the others all used advanced aerodynamics. The MoS felt that the current knowledge of aerodynamics, and to some extent powerplants, was not sufficient to enable any of the advanced types to be constructed with any degree of confidence, although it seemed that one of them was more likely to meet the objective than the less advanced layouts. In addition, the long-range Bristol 172 had also been considered and was thought sufficiently promising to justify the construction of a half-scale model (the Type 174 in Chapter Three). The 172 was no more advanced than some of the B.35/46 submissions and it was felt reasonable to consider it in any general planning programme. If a long-range bomber was to be in operational use by 1958 the design of a prototype must begin not later than 1952.

The Tender Design Conference, held at the Ministry of Supply on 28th July 1947, was chaired by Stuart Scott-Hall, PDTD. He began by saying that Bristol had proceeded with a design study (the Type 172) to the original long-range requirement, but it was realised there would be great difficulties in meeting it and so no specification was raised and no order placed. However, flying models were planned.

Of the six medium-range tenders, the Shorts, AWA, HP and Avro schemes represented aerodynamic conceptions as advanced as the Bristol 172 while the semi-conventional EE and Vickers did not meet B.35/46 in full. In addition, Shorts had been working for over two years on a bomber of conventional aerodynamic layout (the B.14/46) and early in 1947 it had been agreed to place an order for this design as an insurance against the more ambitious B.35 46. The EE and Vickers designs bore comparison with the Short B.14/46 and, thus, the meeting was to consider two different aspects:

a. Selection of the best type or types from Short, AWA, HP and Avro;
b. Whether any change to the B.14 46 order was necessary in the light of the EE and Vickers tenders. In the event it was agreed the Short S.A.4 should continue as ordered except for possible improvements to the engine layout.

The Vickers Valiant prototype WB210 flew for just eight months before being lost. Shorts

AVM Boothman, ACAS(TR), explained that a bomber having the greatest possible chance of penetration was vital to national defence and there should be no hesitation in proceeding boldly with the most promising design, even if development risks were incurred. It was agreed that a prototype of any design must be available in five years while flying models should be built in parallel with the prototypes. The results from such models would be available more than a year before prototype completion which would allow any necessary major alterations to be made in time.

There were difficulties in assessing the stability and control of the four proposals. High-speed tunnel testing on a model of the de Havilland DH.108 research aircraft with conventional ailerons showed that control power vanished at Mach 0.9; full-span elevons were also tested on the Boulton Paul Delta (P.111) and here control power for small control angles was lost at Mach 0.93. The bomber projects were all cruising close to their critical Mach number and increases in thrust could not therefore improve performance. It was noted that Avro's Delta had plenty of room available for extra equipment or fuel when none of the other three could be similarly overloaded except by adding external tanks.

It was thought the Shorts all-moving wing tip would be effective up to the full Mach number of its project but the only real flight experience on such a feature was on the original Pterodactyl, an aircraft that was only lightly loaded. Reference was made to the greater weight and less manoeuvrability of this design compared to the others, and also its higher tyre pressure which affected runway design, so on these grounds it was agreed the S.B.1 could be eliminated from further discussion. The AW.56 would be simpler, cheaper and quicker to manufacture than the other two; the Avro Delta was a practical manufacturing design. There was a need for flying models with both HP and Avro projects since they involved a technical risk which was not entirely removed by wind tunnel tests; HP's in particular involved a totally untried wing planform. Avro's was clearly the most promising, the HP.80 second and AW.56 third. Objections to the latter were the greater fuel load and all-up-weight, lesser manoeuvrability and inferior radar layout.

It was agreed an order should be placed for the Avro 698 and for a flying model to be designed and built in parallel. RAE Farnborough would undertake priority high-speed tunnel tests on the HP crescent wing, following which a choice would be made between this and the AW.56; if the HP.80 was chosen then a parallel model was also wanted. There were to be no changes in the plan to have flying replicas of the Bristol 172. In due course, crescent wing tunnel testing gave promising results which indicated satisfactory stability and trim up to Mach 0.93, so clearing the way to proceed with the HP.80.

After the conference the Air Staff and MoS agreed that the importance of the medium bomber was such that a further type must be ordered between the two extremes of B.35 46 and B.14 46, which was the reason why AWA, EE and Vickers were invited to produce revised brochures. It was recognised that the Avro and HP bombers were very advanced designs with many unknowns and the new work was prompted by some relaxations from B.35 46. Briefly the Air Staff would be content with the carriage of a single 10,000lb (4,536kg) bomb and its accurate delivery at a radius of 1,500 miles (2,413km) while accepting a speed limitation below an altitude of 25,000ft (7,620m). Thus an aircraft of better performance than the B.14/46 should result but taking less risks than the B.35/46s and requiring less-prolonged development and testing.

A Design Study Conference was held on 15th January 1948 where the revised AW.56 was immediately ruled out since it was a tailless design and relied on suction to achieve adequate lift at low speed and to preserve lateral control, features that placed it beyond the interim class now envisaged. However, AWA had by this time informed Scott-Hall it was changing its policy and would like to submit a new design with a tail but H M Garner, PDSR(A), felt the company would not put serious effort into a tailed design and so no formal invitation was made for a resubmission. Scott-Hall stated that on broad aerodynamic grounds, the EE approach was correct by RAE standards, the Vickers incorrect, but in regard to items such as equipment and crew layout, the Vickers design appeared much better. There was also the need to keep Vickers employed while EE was fully loaded with Canberra work. Scott-Hall thought the issue of retaining Vickers in the industry was of paramount importance. It was essential to order this bomber with minimum delay since the Lincoln was by present standards completely out of date, so both companies were to be advised of the objections to their designs and asked to resubmit with the utmost urgency.

In fact, by early February 1948, all three companies had submitted further 'intermediate bomber' brochures. EE modified the wing of its earlier aircraft to have 30° leading-edge sweep at the root with reduced sweep further out. AWA's had a constant 30° sweep but now featured a tail. T V Somerville, assessing them as part of the RAE's Advanced Bomber Project Group, concluded both the EE and Vickers would be much heavier than estimated, EE's offering few, if any, compensating advantages, so it must be rejected. Nothing was gained from using six engines bar the extra weight while the limitation to its diving speed also counted against it. Though admittedly experimental, AWA's smooth wing skin based on the AW.52 was relatively inefficient from a weight point of view.

AWA's and Vickers' designs were similar in performance and it appeared impossible to choose between them on technical grounds. Both were good compromise designs for an interim bomber and final selection might depend on the design ability and productive capacity of the companies concerned. The Vickers project was the one chosen for production and B.9/48 was raised in July 1948 to cover it. By accepting a drop in performance over B.35/46 it was hoped to avoid the lengthy development period of the advanced designs but the anticipated performance was expected to be better than the Short B.14 46. Cruise for B.9/48 was to be 535mph (861km/h) at 35,000 to 45,000ft (10,668 to 13,716m).

The second Valiant prototype, WB215, shows its revised air intakes.

Sperrin, Valiant, Victor and Vulcan

Go-ahead for four medium bombers was now approved but the production plans for the S.A.4 were finished by the Vickers B.9/48. In March 1950, the Treasury was informed by the MoS that there was no longer any justification in spending money on the S.A.4 as an operational aircraft and cancellation of the contract had been considered. There was still a desire, however, to complete two prototypes for flight test work to expedite by 18 months the readiness for service of the V-bombers. Estimates indicated a further £0.87m were needed to complete the two aircraft following the £1.15m already spent, the Ministry indicating that about one third of the extra money would have to be spent anyway in order to keep the contractor occupied until other work became available. Accordingly, the Treasury agreed to the completion of both S.A.4s.

There was also the need to avoid damaging Shorts' design team and on 13th March F C Musgrave, US(Air), proposed to continue the contract until another, for a large flying boat to R.2/48, provided an alternative. Musgrave stated that R.2/48 'would be placed with the company'; in fact the Saunders-Roe P.162 Duchess project won that competition. The first S.A.4 flew on 10th August 1951. After it was unveiled at that year's Farnborough Show, *Flight* reported some general criticism that the aircraft was 'conventional' rather than being more 'characteristic of the "jet era" with sweepback, buried engines and so forth'. (Shorts had favoured fitting a swept wing in order to improve the speed).

In May 1950 it was agreed to complete the second machine as a flying laboratory for ballistic research work and H2S/NBC development. Shorts disliked the 'flying laboratory' designation, preferring 'research aircraft', and on 19th September offered the name Stormont. The MoS would not agree to either so B.14/46 was retained until, in 1954, the S.A.4 was named Sperrin. Both machines were successfully employed on trials and research, a role that included dropping dummy Blue Danube bombs and replacing the lower Avon in each nacelle with the far more powerful de Havilland Gyron for a combined total thrust of 53,000lb (235.6kN). In the meantime Shorts had examined an S.B.1 with four Rolls-Royce Conways, and a design using an S.B.1-style fuselage, a delta wing and four engines in the roots. Span was 103ft (31.4m) and wing area 3,500ft² (325.5m²).

In February 1948 Vickers put forward a design study for a thinner-winged aircraft but an MoS meeting on 23rd March concluded that this had several disadvantages and might take an extra two years to develop, so becoming a competitor to the Avro and HP projects. It was agreed to order the aircraft with the original wing and Vickers received instructions to proceed with two prototype B.9/48s on 16th April. With a deterioration in the situation regarding the Soviet Union, particularly after the Blockade of Berlin in 1948, there was increased urgency to get the aircraft into the air. The first Type 660 flew on 18th May 1951, ahead of the S.A.4 and seven months ahead of schedule. A production order was placed in February 1951 and in June the aircraft was named Valiant (Vickers had wanted Vimy but the Air Ministry refused). The first squadron was formed in February 1955.

The overall HP.80 design was approved in December 1947 following ITP on 19th November for both flying model and full-scale aeroplane, but there were concerns about the flutter effects on the tip fins and rudders. In January 1948 these were deleted and replaced by a more conventional central fin and rudder which increased the span to 110ft (33.5m), added 500lb (227kg) in weight but helped with the flying model's construction. Contracts for two HP.80 prototypes were placed in March 1949 and the first production order followed in June 1952. Production specification B.128P was raised in September and the prototype flew on 24th December. Service deliveries began in November 1957.

Despite Avro's 698 being declared best project at the Tender Conference, contract placement was held up until the MoS was satisfied that the technical strength of the Avro team was sufficient to handle the programme. Two prototypes, a mock-up and flying models were cleared for ordering in December 1947. On 6th April 1948 Avro released a Design Development brochure which highlighted a number of changes made to the original configuration in order to solve the numerous problems that had arisen.

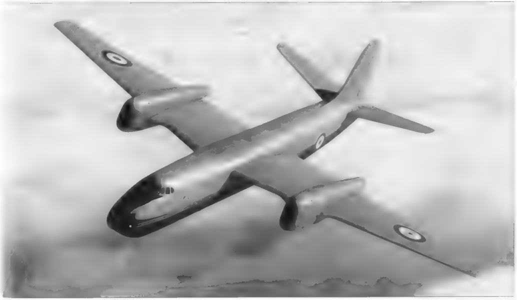
RAE high-speed tunnel tests had revealed a need to retain adequate control at air speeds exceeding Mach 0.9, the solution being the addition of all-moving pointed wing tips outside the tip fins. This caused a considerable aft movement of CofG necessitating a complete re-disposition of equipment. Wing t/c ratio was also cut from 12% to 10% to increase critical Mach number to 0.88 and cut low-speed profile drag, which meant the engines could no longer be stacked but were mounted side-by-side. It was found preferable to use a single bomb bay on the centreline instead of two outside the engines. Span rose to 99ft (30.2m), length dropped to 86.75ft (26.4m) and all-up-weight was 101,764lb (46,160kg); sea level rate of climb 6,900ft/min (2,103m/min).

The first 698 prototype flew on 30th August 1952 by which time, like the HP.80, the tip fins had been dispensed with and replaced by a central fin and rudder; production specification B.129P was raised on 25th September after an initial production order was made in July. Avro considered the name Ottawa (to reflect its Avro Canada connections) but this was turned down. The MoS discussed a host of alternatives but the CAS wanted V-names to go with the Valiant, offering Vulcan (for Avro) and Victor (HP) on 3rd October 1952; this was agreed on 4th December thus creat-

Opposite, top: **The first Short S.A.4 Sperrin VX158 photographed on the day of its first flight, 10th August 1951.**

Opposite, bottom: **For its public debut at the 1951 Farnborough Show, VX158 received an attractive blue, red and black colour scheme.** Short Bros

Below: **Production Vickers Valiant B Mk.1 XD861.**



ing the V-Force. The RAF received its first Vulcans in January 1957.

During the latter part of 1951 and early 1952 the Air Ministry was led to believe that the MoS was preparing an appreciation to show which of the B.35/46s should be bought in quantity for the RAF. At the end of this period it seems no-one was prepared to commit themselves in favour of one type or the other and many reasons, political and otherwise, were put forward to justify a production order for both the Avro and HP aircraft. Thus, by July 1952, although neither of the prototypes had flown, a production order was placed for 25 of each series aircraft.

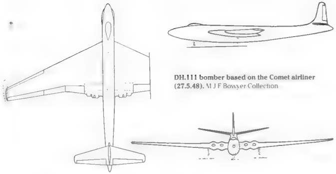
B.35/46 was a bold specification and perhaps the most illuminating point from these designs is the mix of advanced wing shapes then under consideration; they make a fascinating series and, at the time, must have appeared quite extraordinary. Many have written that Britain's aircraft designers were slow to adopt the advanced aerodynamic shapes that became available after the war, with so much German data to back them up. Yet, in Spring 1947, just two years after war's end, British designers were offering swept wings, a delta wing, a crescent wing and two flying wings to one of the most important requirements so far. With 50 years of hindsight it seems a huge waste to build four different bombers, and put three into production, all to satisfy the same need. However, documents from both industry and Ministry suggest a degree of nervousness towards these shapes and their capabilities which made a strong case for back-up insurance types. In the event all four bombers performed well so such insurance may seem unnecessary, but perhaps that was just good fortune since the concurrent fighter programmes suffered far worse with major development problems on both Hawker Hunter and Supermarine Swift.

In 1978 Air Marshall Sir Geoffrey Tuttle, formally DOR and ACAS(OR), wrote in *RAF Quarterly* that the [HP] crescent and [Avro] delta wing types were 'regarded by the Ministry of Supply as rather a technical gamble, and an insurance was taken out in the form of an aircraft which emerged as the Valiant. It is not easy to see why such a plethora of machinery was produced, but I believe the real reason was that the effect of the atom bomb on war had not got through to the Ministry of Supply, which wanted a big industry to fight another big and long war...Korea kept the ball rolling and Mr Attlee [the Prime Minister] had a defence budget of £4,700m for three years. So all the projects went ahead'. Despite their improved performance, the V-bombers had to stay in the medium bomber category because America had now built its huge B-36 and B-52 bombers which took the term 'heavy bomber' up to an altogether different level.

A spectacular view of the first Vulcan prototype VX770. Eric Morgan Collection

De Havilland DH.111

There is one final design to B.35/46 which falls outside the main story. De Havilland (DH) did not tender to the specification but on 27th May 1948 completed a brochure for a military adaptation of its DH.106 Comet airliner called the DH.111. The company had been invited by the MoS to produce such a project some months earlier. DH.111 did not fully meet B.35/46, falling short in cruise speed and maximum permissible Mach number, but DH felt it represented the most advanced aeroplane which could be ready in a reasonable time with a certainty of success, when the extremely unorthodox bombers now proposed might take very much longer to develop than presently estimated. DH.111 was based on an aircraft being built when all the rest still only existed on paper.


DH.111 bomber based on the Comet airliner (27.5.48). M J F Bowyer Collection

It was proposed to make a new fuselage of much smaller cross-section than the DH.106 but leave the rest almost unchanged except for the centre section across the fuselage; the wing was mid-set rather than the Comet's low position. The prototype DH.106 was expected to fly in about a year which meant, since the control and performance characteristics would be known from the civil prototype, virtually a prototype of the bomber would be flying several years earlier than would normally be the case. From a production point of view the wing, empennage (slightly altered to suit the smaller fuselage), main undercarriage, control surfaces and flaps were identical with the advantage of jigs and tools already in existence. The bomb bay was designed for a single 10,000lb (4,536kg) or eighteen 1,000lb (454kg) bombs; providing stowage for the specified alternative loads would entail a much larger fuselage. The huge H2S scanner was housed in the nose and needed 'swollen cheeks' in the fuselage to fit. In true Mosquito fashion, DH left out any unnecessary equipment to save weight, and reduced the crew from five to four.

Power came from four DH Ghosts and a 15% increase in take-off thrust was being explored by using water or water-methanol injection. For military service de Havilland Engines expected that the use of improved hot area materials would allow an appreciable increase over present engine ratings in four to five years. A total of 2,400gal (10,913lit) of fuel was in the fuselage and 3,950gal (17,960lit) in the stub wing for a still air range of 3,720nm (6,893km); take-off wing loading was 51.9lb/ft² (253.4kg/m²). Split flaps were used inboard, plain flaps outboard of the engines to the ailerons and wing tip leading-edge slats were fitted. Bomb drop height when using full engine power was 50,000ft (15,240m).

RAE and the MoS studied the DH.111 closely and fully re-estimated the weight and performance figures. It was not certain all the equipment could be stored in the proposed body, while stowage of the 10,000lb special bomb might lead to difficulties. DH had assumed a streamlined form for the bomb and, even then, could only stow it by introducing a bend in the rear spar. If provision was needed for the full cylinder, then a deeper fuselage and longer undercarriage might be needed together with engine nacelles and a consequent reduction in performance. It was estimated that the first DH.111 would not fly inside two and a half years, i.e. about the same time as the Short B.14/46. Initially the MoS considered it might make a useful insurance to the other B.35/46 projects but, at the end of September 1948, Air Cdr T G Pike, DOR(A), noted that, as there were already five bombers being developed and there was no good advantage in this proposal, he did not consider 'that we should go any further' with it.

Medium Bomber Projects – Estimated Data

Long-Range Bombers to OR.230

Project	Span ft in (m)	Length ft in (m)	Wing Area ft² (m²)	t/c %	All-Up-Weight lb (kg)	Powerplant Thrust lb (kN)	Cruise Speed Height mph (km/h) ft (m)	Weapon Load lb (kg)
Short S.A.4 (6-engine)	154 0 (46.9)	128 6 (39.3)	3,615 (336.2)	12	158,890 (72,073)	6 x RR AJ.65 6,500 (28.9)	475 (764) at 50,000 (15,240) [revised 4.46 480-500 (772-805)]	2,120 (962) total weight
Short S.A.4 (4-engine)	112 0 (34.1)	123 0 (37.5)	2,685 (249.7)	12	115,000 (52,164)	4 x AJ.65 6,500 (28.9)	465 (748) at 40,000 (12,192)	2,120 (962) total weight
Bristol 172	110 0 (33.5)	100 0 (30.5)	2,560 (238.1)	12 to 8.5	166,000 (75,298)	4 x Bristol BE.10 9,000 (40)	600 (965) Mach 0.91 at 40,000 (12,192)	24,000 (10,886) max. 10,000 (4,536) standard
Handley Page HP.72A (HP.80)	122 0 (37.2)	92 0 (28.0)	2,100 (195.3)	16 to 9	90,000 (40,824)	4 x scaled AJ.65 5,600 (24.9)	520 (837) Mach 0.79 at 50,000 (15,240)	10,000 (4,536) standard

Medium-Range Bombers to B.35/46 (OR.229)

Armstrong Whitworth AW.56	120 0 (36 6)	80 0 (24.4)	2,611 (242 8)	13 root 10 tip	113,000 (51,257)	5 x Avon AJ 65 6,500 (28 9)	582 (936) at 36,000 (10,973)	1 x 10,000 special, 2 x 10,000 (4,536) HC, 3 x 6,000 (2 722) or 19 x 1,000 (454)
Avro 698	91 6 (27 9)	92 0 (28 0)	3,364 (313)	12 root 12 tip	104,000 (47,174)	2 x BE 10 9,140 (40 6)	584 (940) at 49 000 (14,935)	2 x 10,000 special HC, 4 x 6,000 (2,722) or 20 x 1 000 (454)
English Electric B.35/46	100 0 (30 5)	97 0 (29.6)	2,000 (186)	14 root	84,000 (38,102)	6 Napier Arm Sidd 4,850 (21.6)	518 (833) at 49,000 (14,935) to 60,000 (18,288)	1 x 10,000 special HC, 3 x 6,000 (2,722) or 18 x 1,000 (454)
Handley Page HP.80	100 0 (30.5)	91 6 (27 9)	2,000 (186)	14 root 8 tip	95,000 (43,092)	4 x MetroVick F 9 7,500 (33 3)	576 (927) at 50,000 (15,240)	1 x 10,000 special, 2 x 10,000 (4,536) HC, 3 x 6,000 (2,722) or 21 x 1,000 (454)
Short S.B.1	114 0 (34 7)	86 3 (26.3)	2,385 (221.2)	13 root	115,000 (52,164)	4 x Avon AJ 65 6,500 (28.9)	576 (927) at 47,000 (14,326)	1 x 10,000 special, 2 x 10,000 (4,536) HC, 2 x 6,000 (2,722) or 21 x 1,000 (454)
Vickers B.35/46	137 0 (41 8)	111 0 (33.8)	2,350 (218.6)	13 root 12 tip	115,000 (52,164)	6 x Napier E 131 5,055 (22 5)	557 (896) at 45,000 (13,716)	1 x 10,000 special, 2 x 10,000 (4,536) HC, 3 x 6,000 (2,722) or 24 x 1,000 (454)
de Havilland DH.111	115 0 (35 1)	95 0 (30.0)	2,024 (188.2)	11.5	105,000 (47,628)	4 x DH Ghost 5,700 (25 3)	518 (833) at 50,000 (15,240) (maximum power)	1 x 10,000 special HC, 2 x 6,000 (2,722) or 18 x 1,000 (454)

Revised Brochures – B.35/46 Relaxation

Armstrong Whitworth AW.56	102 0 (31.1)	75 0 (22.9)	2,250 (209.3)	13 root 10 tip	101,150 (45,882) 97,200 (44,090)	4 x RR RB 77 7,500 (33 3) or 4 x Avon AJ 65 6,500 (28.9)	575 (925) at 36,000 (10,973) 547 (880) at 40,000 (12,192)	1 x 10,000 special, 2 x 10,000 (4,536) HC, 3 x 6,000 (2,722) or 14 x 1,000 (454)
English Electric	100 0 (30.5)	108 0 (32.9)	?	?	111,150 (50,418)	6 x Avon AJ.65 6,500 (28 9)	547 (880) at 51,000 (15,545)	?
Vickers B.35/46	136 3 (41 5)	114 6 (34.9)	2,490 (231.6)	12	110,000 (49,896) 110,000 (49,896)	4 x AS Sapphire 7,500 (33.3) or 4 x Avon AJ.65 6,500 (28 9)	570 (917) at 45,000 (13,716) 553 (890) at 45,000 (13,716)	1 x 10,000 special HC, 2 x 6,000 (2,722) or 18 x 1,000 (454)

Intermediate Bomber – Final Brochures ('B.9/48' – OR.229)

Armstrong Whitworth (with tail)	100 7 (30.7)	101 4 (30 9)	2,120 (197.2)	11	104,350 (47,333)	4 x Avon AJ.65 6,500 (28.9)	541 (870) at 44,800 (13,655)	?
English Electric	100 0 (30 5)	108 0 (32 9)	2,500 (232.5)	12	111,150 (50,418)	6 x Avon AJ.65 6,500 (28 9)	547 (880) at 51,000 (15,545)	?
Vickers	113 4 (34.5)	101 6 (30.9)	2,320 (215.8)	12	107,000 (48,535)	4 x Avon AJ.65 6,500 (28.9)	535 (861) at 45,000 (13,716)	?

'As Flown'

Short S.42/S.A.4 Sperrin (B.14/46 - OR.239) (First Prototype)	109 1 (33 3)	102 2 (31.2)	1,897 (176.4)	12	115,000 (52,164)	4 x Avon RA.2 6,000 (26.7)	564 (907)	1 x Blue Danube or conventional
Avro Vulcan Mk.1 (B.129/OR.229/3)	99 0 (30.2)	97 1 (29.6)	3,554 (330 5)	8 tip 12.3 root	170,000 (77,112)	4 x Olympus 101 11,000 (48.9)	620 (998) at height	Nuclear or 21 x 1,000 (454)
HP Victor B Mk.1 (B.128/OR.229/3)	110 0 (33.5)	114 11 (35.0)	2,406 (223 8)	6 tip 16 root	180,000 (81,648)	4 x Sapphire 202 11,050 (49.1)	645 (1,038) at height	Nuclear or 35 x 1,000 (454)
Vickers Valiant Mk.1 (B.9/48/OR.229)	114 4 (34.8)	108 3 (33 0)	2,362 (219.7)	12 root 9 tip	175,000 (79,380) maximum	4 x Avon 201 10,000 (44.4)	567 (912) at height	Nuclear or 21 x 1,000 (454)

Chapter Three

V-Bomber Encore

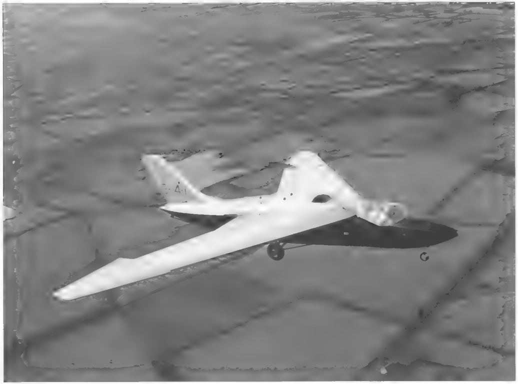
An eye-catching view of an Avro 707A, from the 'dark' colour scheme possibly WD280. The 707A to E.15/48 was the high-speed replacement for the abandoned Avro 710. Eric Morgan Collection

Test Aircraft and Further Developments: 1947 to 1960

What were the factors and effects of designing bombers powered by the newly introduced jet engine? A March 1948 report by Air Cdr G R C Spencer, recently the Commandant of the Central Bomber Establishment, revealed some of the *Implications of the Jet Bomber*. The main limitations with early jet engines were restricted conditions for efficient operation and a high fuel consumption, especially at low altitude. The jet could be comparatively efficient provided it was working under its own conditions of high speed and great height. Although the thrust decreased with height, aircraft drag decreased in greater proportion and both the thermal and overall efficiency of the engine increased appreciably.

Fuel consumption at maximum height for an engine of 6,500lb (28.9kN) thrust was 200gal (909lit) per hour which meant that a lot of fuel was needed to fly a long way; one problem was that throttling back did not appreciably reduce consumption. A range of 4,000 to 5,000 miles (6,436 to 8,045km) would need a very big aircraft to hold the large volume of fuel required, about one-third of the total weight, and the bomb load would be a relatively small proportion of this weight. Spencer calculated that a bomber having a bomb load of 20,000lb (9,072kg) and a total engine thrust of 26,000lb (115.6kN) would need 7,500gal (34,102lit) of fuel to achieve a range of 4,500 miles (7,241km); maximum weight would be about 160,000lb (72,576kg).

From a flying point of view, it was the primary aim of every designer to produce a bomber with as high a Mach number as pos-



sible. This gave a good engine efficiency and the lowest possible difference in speed between his bomber and its opposing fighters, thus reducing the chance of interception. If the bomber could get close to the sonic barrier, the fighter could not get much nearer unless it passed through the barrier (a capability which in 1948 was seen to be some time away) and a margin kept within 40 to 50mph (64 to 80km/h) invalidated much of the case for arming the bomber. Removing the defensive armament made the designer's job easier but achieving a high Mach number (0.9 was the objective) brought extra complication to the design such as the need to use swept wings.

To get the maximum range from a jet aircraft, it would need to climb at full thrust, as steeply as possible, to its operational height. It would then climb gradually to maintain the operational height which increased as the aircraft became lighter through the consumption of its fuel. Since it was necessary to keep as high as possible for as long as possible, the gradual climb due to decreasing weight had to be maintained on the return flight until it was time to lose height preparatory for landing. Besides these aerodynamic aspects, introducing jet bombers also brought far-reaching long-term changes in ground organisation and airfield design.

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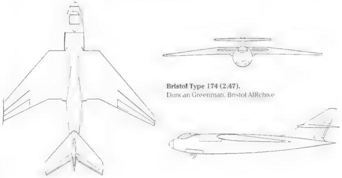
The V-bomber story did not end with the entry into service of the types described in Chapter Two; there were also more advanced developments and the scale model test aircraft described in this chapter. Several replica aircraft were built to assist the bombers' development programmes and aviation research overall. As far as possible it was hoped that aerodynamic development problems could be solved in the wind tunnel but, at this time, there was no equipment available in the UK or elsewhere capable of solving every difficulty. Some could only be answered in flight and, in general, it was felt that this could be done at less expense and more quickly by using flying models.

When the V-bomber programme began, AWA already had a scale model test vehicle under way for bombers and large aircraft. The first AW.52, TS363, flew on 13th November 1947 and this view shows it in slow flight mode with everything down. AW.52 was a beautiful aeroplane. AIR-Britain

Shorts' scale model glider for its B.35/46 S.B.1 bomber project also began life with the S.B.1 designation, flying on 14th July 1951. Rebuilt as the S.B.4 Sherpa with two small jets, it flew again on 4th October 1953. Here the wing tip controllers are seen to advantage. Shorts



Bristol Type 174 (2.47).
Duncan Greenman, Bristol AIRchive

Display model of the Bristol 176.
David Charlton, BAe Filton

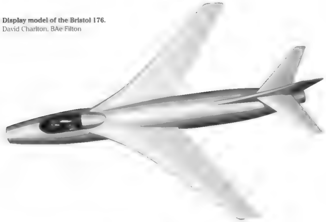
Short S.B.1

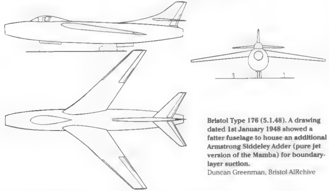
Despite Shorts' S.B.1 being rejected, the company persevered with its 'aero-isoclinic' studies and constructed a one-third scale glider which also was designated S.B.1. Keith-Lucas was satisfied that there was much in Hill's wing proposal but realised the research to prove it must be planned carefully. The glider was towed into the air on 14th July 1951 but crashed on its second flight. Rebuilt with Turboméca Palas jets it became the S.B.4 Sherpa and flew under its own power on 4th October 1953. In July 1953 a high-speed research vehicle called the P.D.10 was proposed using a Supermarine Swift fuselage but it was not built.

Bristol 174 and 176

The Bristol Type 172 was never ordered, but the design was thought sufficiently promising to justify the construction of a scale model. Two Type 174 four-tenths scale flying models, serials VX317 and VX323, were ordered to E.8/47 and OR.250 in May 1947, possibly the first contract to be placed in regard to OR.229 and OR.230. The machine was to have power controls and 574gal (2,610lit) of internal fuel. Initial plans called for an orthodox swept tail and fin but a 172 style swept V-tail, and boundary layer control, would be introduced later. The objective was to obtain more high and low-speed swept wing knowledge; sweep angle was 45°. Work began at Bristol in 1947 and reached the stage of loft plates and tooling with a shop allocated for manufacture, but it was stopped when the wing/body junction shape was found to be unsatisfactory; the project was eventually replaced by a second aircraft called Type 176. The efficiency of the 174's powerplant installation, with the sharp angles needed to get the intake air to the Nene, has been questioned.

Display model of the Bristol 176.
David Charlton, BAe Filton





Bristol Type 176 (5.1.48). A drawing dated 1st January 1948 showed a fatter fuselage to house an additional Armstrong Siddeley Adder (pure jet version of the Mamba) for boundary-layer suction.
Duncan Greenman, Bristol AIRchive

The Type 176 three-tenths scale model was to be powered by one of the first production Rolls-Royce Avons and had a limiting Mach number of 0.92. E.8/47 was raised to Issue II in May 1948 to cover the airframes, the first having provision for alternative wing tips, an all-moving tail and at least 360gal (1,637lit) of internal fuel. With time Bristol saw the project more as a pure research aircraft in its own right and gave little thought to putting the Type 172 into production, despite the opinion of T G Pike, DOR(A), that a limited number of 172s should be built if the model proved its worth. Chief Designer was Barry Laight and the 176's purpose became quite simply to fly some swept wings. The Swept Wings Advisory Committee met industry and research representatives at the Royal Aeronautical Society to discuss progress nationally; Bristol's role was to obtain some practical flight experience.

The 176 employed the simplest engine, fuselage and wing combination with a nose intake split around the single-seat cockpit; a bicycle undercarriage was used because of the thin wing. Take-off wing loading would be 56.3lb/ft² (274.8kg/m²). Work stopped after the Mock-Up Conference in October 1948 and the project was cancelled in 1949 to release funds for other developments. A memo from C B Baker at the MoS, dated October 1953, noted that the company 'lost interest and the project was cancelled at the company's request'. Barry Laight told the author that the 176 possibly overcooked the sweep at 45° while the planform, section, twist and tip foils, and the effects of flaps, ailerons and spoilers, were all new uncharted areas of design.

Handley Page HP.88

In April 1948 a contract was issued for HP to build two two-fifths scale models of its bomber called the HP.88. This became very much a combined effort by several companies and followed abandonment of the HP.87 one-third scale glider. Since HP had insufficient Drawing Office capacity, detail design was sub-contracted to General Aircraft where the type was called GAL.63. Soon afterwards General merged with Blackburn so it was retitled Y.B.2, the design work moving from Feltham to Brough. One aircraft was cancelled on 14th October 1949 for economy but the second, VX330, was completed to Specification E.6/48. HP's Reg Stafford visited Supermarine's design office at Hursley Park where it was agreed to use an Attacker fighter's fuselage, but in late February 1948 this was changed to the modified type similar to Supermarine's Type 510 because the fuel tanks were compatible with swept wings (Supermarine called the project Type 521). It flew on 21st June 1951 but broke up in the air during a flight on 26th August.

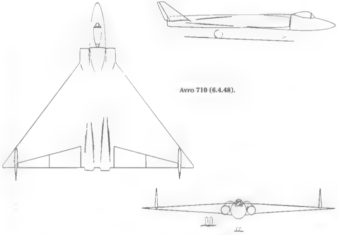
Avro 710 and 707

Avro's B.35/46 Development Brochure of 6th April 1948 (Chapter Two) gave the first details of flying scale models. To investigate the remaining aerodynamic problems surrounding the operation of the delta aircraft at the Mach numbers and altitude required (in particular control and drag reduction at high speed), it was proposed to build a half-scale model called the Avro 710. This would enable a check on performance, control and stability to be made and, using the maximum continuous cruise power of its twin Avons, the aircraft was expected to be capable of cruising at the bomber's specified speed of 575mph (925km/h) at up to 60,000ft (18,288m) if required. The 710 would be a true model (with certain minor deviations) and had the all-moving pointed wing tips outside the fins introduced to the 698 at this time. Sea level climb rate was predicted to be 8,250ft/min (2,515m/min) using a constant EAS of 224mph (360km/h) but much higher climb rates, particularly near sea level, were possible by using higher speeds. It carried 820gal (3,728lit) of fuel in the wings and would fly in 21 months.

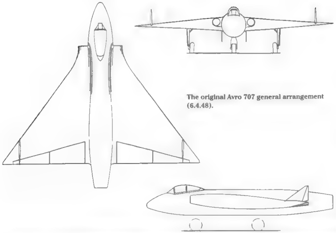
Simulating the full-scale aircraft much less closely, a smaller one-third scale Avro 707 would assess the equivalent problems at low speeds and altitudes. Unless any low-speed and low-altitude control and stability problems were overcome, the high-speed qualities of the aircraft were of no practical significance. The idea was to make the 707 far easier to produce than the all-metal 710 by using mostly wood construction together with existing standard items such as undercarriage and controls; in such simple form it would not be designed to high-speed parameters. Using a Rolls-Royce Derwent V, performance was expected to be 400mph (644km/h) up to 10,000ft (3,048m), enabling all preliminary aerodynamic investigation to be undertaken in flight, particularly the problems concerning landing of the delta aircraft. First flight was expected in about a year.

By 6th April Avro had begun work on both. This lengthy programme of development using flying models was felt to be justified because it enabled knowledge not obtainable by any other means to be gained as quickly as possible. There would be no mock-ups of these scale models. J E Serby was enthusiastic about the rapid-build 707 since it

The Handley Page HP.88 flew on 21st June 1951 but tragically crashed two months later. It was painted Royal Blue with the roundels and lettering outlined in silver. BAE Systems, Brough



Avro 710 (6.4.48).



The original Avro 707 general arrangement (6.4.48).

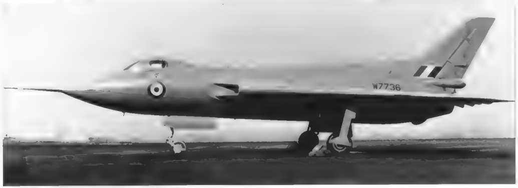
Below: **Avro 707 prototype VX784 seen in September 1949, shortly before the aircraft was destroyed in a crash.** Avro Heritage Centre

Bottom: **The second 707A was WZ736, first flown in February 1953. The most obvious difference was the use of wing-root intakes. This aircraft was used for research into automatic throttle development.** Avro Heritage Centre

Photographs on the opposite page

Like Avro 707 VX784, Avro 707B VX790 was used to investigate the low-speed stability of delta wings. First flown in September 1950, this aircraft's delta wing had a 51° leading-edge sweepback.

The famous flypast by the two Avro 698 Vulcan prototypes and four 707s over Farnborough in September 1953. VX777 had flown for the first time just a few days previously on 3rd September. Eric Morgan Collection



offered knowledge quickly and would push enthusiasm for the delta bomber, a very revolutionary design. An ITP was given for both models on 8th June with serials VX799 and VX808 allocated to the 710s, VX784 and VX790 to the 707s; a contract letter was sent to Avro on 6th July for two 707s (and two 698 prototypes).

However, in July RAE suggested that the 710 design job would be nearly as big and as difficult as a proposed full-size 'flying shell' 698, and both scale models were useless from the structural standpoint. They considered the 710 should be dropped and on the 26th Serby wrote to Avro suggesting it was quicker to do just the one model – did Avro agree? Avro's W S Farren gave his support on 14th September and suggested increasing the 707s to three by adding a high Mach number machine with a different intake and stiffer structure. There were insufficient staff to handle all the projects simultaneously, the 710 would seriously delay the full prototype while developments on the 698 made it more difficult to reproduce certain essential features sufficiently closely, or at all, on the 710. Farren felt the move would advance the full 698 prototype by a year. This was accepted.

Avro designer J G Willis had prepared the additional one-third scale 707 by 26th Octo-

The sole Vickers Valiant B Mk.2 prototype, WJ954, probably taken on 11th September 1954 during the build up to the Farnborough Show. The all-black night flying scheme earned it the title of the 'black bomber'. Eric Morgan Collection

ber and explained that the aircraft seemed quite strong enough to operate to the same Mach number limits as the 698. Serby agreed this change of plan would save time, though the half-scale machine was not finally cancelled until 15th February 1949. The 'flying shell' 698 (to E.11/49) was also dropped. Specification E.15/48 was raised for the two original 707s, the first flying on 4th September 1949 with a single fin, and E.10/49 covered later examples of which three were eventually built.

Returning to the three V-bombers, further variants were proposed to fulfil a specific role or to give more general improvements in capability. Some of these variants entered service, others stayed on the drawing board.

Vickers Type 673 Pathfinder

The Valiant B Mk.1 was the only variant to reach a squadron but in September 1948 Vickers proposed a target marker version intended to fly over its target at low level (5,000ft [1,524m]) and high speed. At the time, this was a very forward-looking idea since bombers were expected to fly at ever higher altitudes. Due to the structural loads involved with flight at sea level, the Valiant Mk.1 was limited to 414mph (666km/h) whereas the 673 would be stressed to fly much faster. In August 1949 the company proposed a bicycle undercarriage for this aircraft but it was not adopted. OR.285 was raised for the Pathfinder in July 1950, for introduction into service concurrently with the other V-bombers, and specification B.104D was issued along with the first prototype order in November. The aircraft was to perform both target marking and bombing and became the Valiant B Mk.2. Carriage of the Blue Boar guided bomb was stated in January 1952 having been added to OR.229 in February 1950.

In January 1949 Vickers reported that the first Valiant Mk.1 prototype was to have Avon engines, the second Sapphires, the nacelles in both aircraft being capable of taking either type without modification. There was the possibility of replacing them later with the Bristol Olympus or Rolls Conway. In April 1951 it was agreed that the first Mk.2 should have Avon RA.14s and a contract for twenty-four Mk.1 aircraft and seventeen Mk.2s was placed in October. The major changes on the Type 673 B Mk.2 from the Mk.1 were a considerably strengthened wing and load-bearing structure for higher speeds, a new undercarriage, an extended forward fuselage for extra equipment and a revised bomb aimer's blister (a later long-range version would have extended wing tips and Conway engines). It was the undercarriage that showed the most obvious difference to the original with its four-wheel main gears retracting backwards into underslung pods outboard of the jet pipes.

The programme seemed to be progressing smoothly but in September 1952 the Air Ministry withdrew OR.285 on economy grounds though it was agreed to finish the Mk.2 prototype (which was 60% complete) to assist Mk.1 clearance, and convert the Mk.2 order into B Mk.1s. A dedicated photo reconnaissance Valiant to OR.279 with larger wings and Conway engines was also dropped and replaced by a simple modification to the Mk.1. Ironically, a submission was made to the Treasury the following month for another 56 Mk.1s; it was granted in April 1953 but as 53 Mk.1 and nine B(PR) Mk.1s. The requirement to carry Blue Boar in any Valiant was cancelled in August 1953. The B Mk.2 prototype, WJ954, flew on 4th September and in the following August began RATO trials in support of the Mk.1. It was scrapped in August 1958.

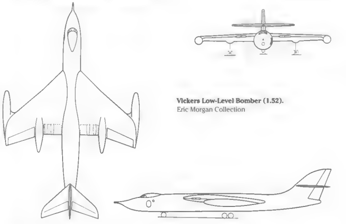
A paper dated 27th April 1956 considered the Valiant as a specialised low-level bomber and concluded that the Mk.1 did not approach the Air Staff's requirements in any respect. The Valiant 2 had the required speed at low level with a performance approximating closely to the requirements but its range was only 50% of the stated limit while carriage of the new 'powered inertia bombs' (Blue Steel) would necessitate a major redesign. However, such a development would give a 30% saving in cost over a more specialised aircraft and the report recommended that a small number of Valiant 2s should be ordered to improve the low-level threat. This plan was never implemented.

However, due to the introduction of SAMs and other advanced enemy defences, most bombers were eventually forced to fly at low level and the Valiant was no exception. In 1964 those still serving in the strike role were switched to low-level operations but by mid-year fatigue cracks were discovered in both the front and rear spars of some aircraft. Rebuilding was rejected and a decision was taken in January 1965 to scrap almost the entire fleet including tanker conversions. It has always been assumed that had the order for B Mk.2s been completed this situation would not have arisen. This seems quite sensible but the planned order for B Mk.2 aircraft appears to have been for small numbers only, so sufficient low-level Valiants might not have been available anyway.

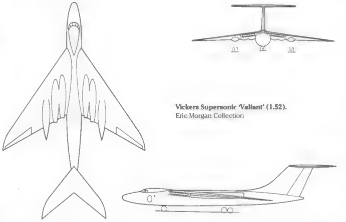
Vickers Low-Level and Supersonic Valiants

There were proposals for supersonic versions of each V-bomber but, at the time of writing, no information has been traced for the Avro 732 supersonic Vulcan. In January 1952 Vickers undertook a combined preliminary investigation for two separate Valiant developments, a dedicated low-level bomber and a supersonic bomber.

The former would operate at relatively low level throughout and carry 10,000lb (4,536kg) of bombs at Mach 0.85 for 4,300nm (7,964km). It was designed around the Valiant Mk.2 but with modified mainplanes and a 10ft (3.05m) extension to the forward fuselage to make room for more fuel. Wing sweep was increased to improve the critical Mach number and a larger tail was necessary to cope with the increased main chord. Any engine from the current 9,000lb to 12,000lb (40kN to 53.3kN) class could be accommodated but maximum take-off weight was 250,000lb (113,400kg). The range needed 306,000lb (138,802kg) so the extra fuel would be taken from a tanker after take-off. Cruise speed at top weight with drop tanks was 600mph (965km/h), without tanks over the target at 200,000lb (90,720kg) weight it was 652mph



Vickers Low-Level Bomber (1.52).
Eric Morgan Collection



Vickers Supersonic 'Valiant' (1.52).
Eric Morgan Collection

(1,049km/h). To reach these speeds needed a total thrust of 28,000lb (124.4kN) which was just possible using four Avon RA.14s but the Conway's unfavourable thrust/speed characteristics would currently only develop about 21,000lb (93.3kN). Initial rate of climb was 1,050ft/min (320m/min) at 306,000lb and 3,320ft/min (1,012m/min) at 200,000lb.

The long-range high-altitude Valiant development was capable of sustained supersonic speed. With four Conway Co.3s, 2,000°K reheat and take-off at 177,000lb (80,287kg) it could reach Mach 1.41 at 50,000ft (15,240m) or Mach 1.2 at the absolute ceiling of 58,000ft (17,678m). Still air range at Mach 0.95 cruise was 3,640nm (6,741km) giving an over-the-target height of 41,000ft (12,497m). Flying 500nm (926km) supersonically cut range to 1,930nm (3,574km) but drop tanks increased these figures to 4,440nm (8,223km) and 2,630nm (4,871km) respectively while reducing maximum Mach number to 1.43 at 36,000ft (10,973m). The engines were cantilevered from the rear spar and fed by intakes which passed under the wing to leave the primary structure unbroken. Using maximum rpm without reheat at 177,000lb take-off, 700mph (1,126km/h) Mach 0.99 was possible at 20,000ft (6,096m), 672mph (1,082km/h) Mach 1.02 at 36,000ft (10,973m).

These projects were prepared as a result of informal discussions between Vickers and the Air Staff and represented preliminary examinations without detail work. The Ministry felt both were indicative of the type of aircraft which could be produced to meet these roles and the low-level bomber in particular was considered a practical proposition. However, Air Commodore G Silyn Roberts described them both as 'very sketchy'.

Vickers Type 722 Valiant Mk.3

In May 1952 the company proposed a Mk.3 Valiant as a replacement for the Mks.1 and 2. Essentially a standard Mk.1, it had a more highly swept wing and a Mk.2 chassis and could fulfil the bomber, reconnaissance or Pathfinder roles. It was designed for a diving speed of 449mph (722km/h) EAS but, due to compressibility losses at sea level, this figure became 501mph (806km/h) when acting as a Pathfinder. On the level at 124,200lb (56,337kg) weight it could reach 564mph (907km/h) at 45,000ft (13,716m). The normal built-in tankage gave a range with a 10,000lb (4,536kg) bomb of 5,100nm (9,450km), with drop tanks this rose to 6,440nm (11,933km). Sea level rate of climb at 132,700lb (60,193kg) weight was 4,900ft/min (1,494m/min) and service ceiling 48,000ft (14,630m).

Victor and Vulcan B Mk.2s

By 1954 the Air Staff had become increasingly concerned about the vulnerability of the V-bombers and so asked the manufacturers to study seriously to what extent the aircraft could be developed. Little improvement in speed was likely and so effort was concentrated on improving height performance. Developing the Victor involved increasing the span by 10ft (3.05m), increasing the chord and the centre section of the wing, and increasing the size of the engine intakes to cater for more powerful engines so that thrusts up to 17,500lb (77.8kN) could be fully absorbed. Handley Page called this the Phase 2A wing and the type entered service as the B Mk.2, the first aircraft flying on 20th February 1959.

An April 1956 report looked at fitting the Bristol Olympus 6 (16,000lb [71.1kN]), Olympus 7 (17,300lb [76.9kN]), Rolls-Royce Conway Stage 2 (14,500lb [64.4kN]) or Conway Stage 3 (16,500lb [73.3kN]) to both Mk.2 Victors and Vulcans; the Olympus gave a slight edge with height, the Conway with range. There was a long debate regarding the merits of each engine since installing greater power in the V-bombers meant plenty of re-design to accommodate it (the two engines are discussed later). The decision to fit Conways in the Victor, instead of the Sapphire 9, was actually made in December 1955 together with a ruling that the new wing should be developed and introduced as soon as possible. The units fitted were Conway Mk.103s of 17,250lb (76.7kN) but engine surge problems postponed the first flight from its August 1958 schedule. Deliveries began on 1st November 1961 and later aircraft had 20,600lb (91.6kN) Conway 201s.

Improving the Vulcan B Mk.2 involved extending and cambering the wing leading edge, thinning the outer wing and increasing both chord and span. This enabled local airflow velocities to be kept subsonic up to a higher aircraft Mach number thus delaying the separation and consequent buffeting as lift was increased. Engine thrusts up to 17,500lb (77.8kN) could then be fully absorbed; Avro called this the Phase 2C wing. It was proposed in August 1955 and Avro turned the second Vulcan prototype, VX777, into a Mk.2 aerodynamic test vehicle, flying it on 31st August 1957 with the new wing and Olympus jet pipes. The first production aircraft flew on 30th August 1958 with 16,000lb (71.1kN) Olympus 200s which were selected for the type in June 1957; later machines had the 17,000lb (75.6kN) Mk.201 or 20,000lb (88.9kN) Mk.301. The earliest Vulcan had been designed to reach Mach 0.95 in a shallow dive but Phase 2C was stressed to cover Mach 1.0.

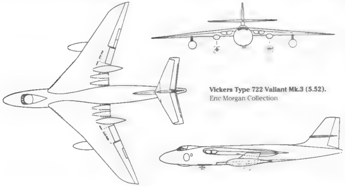
The Vulcan and Victor programmes were split into Phases – Vulcan Phase 1 was the basic airframe as exemplified by the second prototype and early production aircraft, Phase 2 had a drooped 20% chordwise extension to part of the outer wing giving maximum improvement for minimum structural alteration. This was tested on an Avro 707 and showed increased lift coefficient at the buffet threshold, but as more powerful engines became available a more extensive modification was required. Further modifications called Phase 2A and 2B were superseded by Phase 2C.

Phase 3 would have had an entirely new and thinner outer wing constructed of honeycomb sandwich, a new main undercarriage capable of operating at take-off weights up to 220,000lb (99,792kg) and increased fuel capacity. It was proposed in February 1955 with either Olympus 6 or 7s, Super Sapphires or a Conway 5 development; all-up-weights were 100,494lb, 101,143lb, 100,449lb or 98,553lb (45,584kg, 45,878kg, 45,564kg or 44,704kg) respectively (the proposed 'Super' Sapphire offered 50% more thrust at 50,000ft [15,240m] and 575mph [926km/h] than the Sa.9). Phase 3's weakness was the amount of redesign that it required so Phase 2C was adopted instead to give the same improvement in buffet threshold without the severe structural modifications. Altitude performance was very similar to Phase 3 but the latter's outstanding range was lost.

Transition to the Victor and Vulcan B Mk.2 was helped by limited improvements to each B Mk.1 as the B Mk.1A. An improved ceiling would be valuable for survival against current fighter developments while the modest increase in range, a mere 200 to 350nm (370 to 648km), actually increased the number of targets that could be attacked by 25%. In 1957 it was predicted that by 1960/61 the Soviets would have SAGW defences and so the V-bombers would then need to carry the Blue Steel stand-off bomb to hit targets from outside SAGW range; later the longer-range Blue Steel Mk.2 powered bomb to OR.1159 would be introduced (but never carried). The extra weight of these weapons and other planned equipment would require engine thrusts of around 20,000lb (88.9kN).

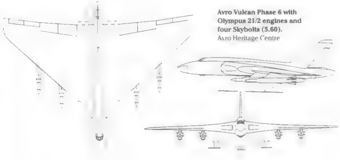
Carriage of Blue Steel was proposed for Mk.1 Vulcans in February 1957 but the lower boom of the centre section front spar was not cranked on these aircraft, making it impossible to submerge the missile beneath the fuselage as much as on Mk.2 aeroplanes. This had an adverse effect on performance and drag and so the weapon was carried on the later mark only, becoming operational in 1963.

In September 1956 the Air Staff discussed removing either Vulcan or Victor Mk.2 from the RAF programme, depending on the size of the V-Force that could be afforded after the



Vickers Type 722 Valiant Mk.3 (5.52). Eric Morgan Collection

XH538 was an early Avro Vulcan B Mk.2; the view shows the modified wing. Avro Heritage Centre



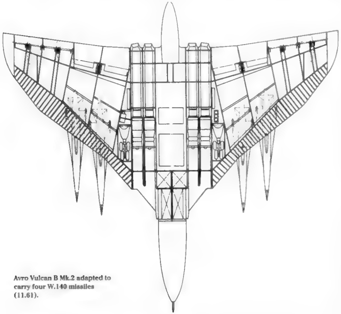
Avro Vulcan Phase 6 with Olympus 21/2 engines and four Skybolts (5.60). Avro Heritage Centre

forthcoming Defence Policy Review. After April 1957 the extra equipment fitted in Mk.2 V-bombers would bring substantial increases in expenditure but more money was expected to be available after that year's Defence White Paper cancelled most of Britain's fighter projects. However, 25 of the 57 Victor B Mk.2s on order were cancelled in July 1960, although South Africa did consider buying Mk.2s in October 1961 to use up components made redundant by the smaller order.

This reduction came from the adoption of the American Skybolt as Britain's principal deterrent weapon instead of the Blue Streak ballistic missile, a major change to defence policy announced by the Minister of Defence, Harold Watkinson, on 13th April 1960. It was felt that the Mk.2 Vulcan would technically make a better Skybolt carrier and this became policy in July, though Handley Page told the MoA on 15th July that the Victor Mk.2 could 'carry two Skybolt missiles without modifications to the aircraft or missile to improve ground clearance'. An easy Phase I conversion could permit a Victor Mk.2 to carry two missiles for 14 hours; Phase II modifications would increase the load to four with the same duration and gain CA Release by 1964/65. A satisfactory take-off performance up to 285,000lb (129,276kg) all-up-weight would be provided by reheated 20,000lb (88.9kN) thrust Conway 17s while two Spectre rockets could be added to allow even higher weights.

The Skybolt Vulcan was proposed in May 1960 as the Phase 6 and was basically a package of modifications designed to be applied retrospectively to the Mk.2. It would use Olympus 21 or 21/2 engines with reheat, the existing intakes and bay installation and carry four GAM-87A Skybolt missiles on underwing pylons (21/2 had the larger turbine of TSR.2's Olympus 22 to give the same performance as the later engine). Other changes included a new wing with greater area and span, an integral tank outboard and bag tanks inboard in the wing, new inner elevons with the existing outer elevons, a dorsal fuel tank behind the canopy, local stiffening of the centre section, fin height increased by 3ft (91cm) and a new main undercarriage with a four-tyre bogie to meet the higher all-up-weight. With Olympus 21/2s, 21,940gal (99,759lit) of fuel and four missiles, all-up-weight would be 339,168lb (153,847kg). Span was 121ft 0in (36.9m), length 99ft 11in (30.4m) and wing area 4,215ft² (392m²). Skybolt was 38ft (11.6m) long and weighed 12,000lb (5,443kg).

A Vulcan/Skybolt modification programme, with OR.1187 covering the weapon, was prepared in October 1960; the first aircraft was to be delivered in March 1963. However, by July 1961 this had still not been agreed between the Air Ministry and MoA, and Treasury approval was still limited to £1m. The first flight of a Vulcan Mk.2 carrying two captive mechanical Skybolts was successfully completed on 29th September with the first successful dummy drops following in December. Eventually, through development problems and rising costs, the Americans cancelled Skybolt and Britain was forced to do the same in December 1962. It was replaced by the submarine-launched Polaris ballistic missile.



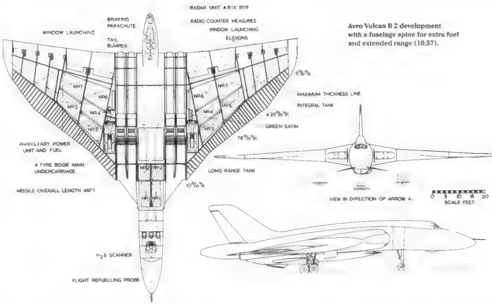
Avro Vulcan B Mk.2 adapted to carry four W.140 missiles (11.61).

Further Vulcan Development Proposals

The Vulcan Phase 5 of November 1956 carried the proposed Avro W.107 powered missile to OR.1149. Missile weight was 23,000lb (10,433kg) and take-off weight with either 20,290lb (90.2kN) Olympus Ol.21s or 20,000lb (88.9kN) Conway Co.31s was either 223,535lb (101,395kg) or 225,000lb (102,060kg). Some Ministry documents suggest that V-bombers carrying the OR.1149 missile would have presented a deterrent superior to the Avro 730 (see Chapter Six).

A November 1961 brochure described the Vulcan carrying two, three or four advanced W.140 missiles, an Avro stand-off long-range weapon to OR.1182. This had a slim body 37ft 3in (11.35m) long with a 6ft 6in (1.98m) span delta wing, a Rolls RB.153-17 jet and all-moving elevons for control aft of the wing. Launch weight would be 8,550lb (3,878kg) and Vulcan all-up-weight 247,828lb (112,415kg) but take-offs were limited to 210,000lb (95,256kg). If the weapon was launched at Mach 0.84 and 45,000ft (13,716m), a range of 1,550nm (2,871km) was possible but this fell to 950nm (1,759km) if the missile flew the last 100nm (185km) at Mach 1.5 at sea level; W.140 would cruise at Mach 3 at 70,000ft (21,336m).

Anticipating the likely cancellation of Skybolt, in November 1962 the Air Staff considered procurement of the BAC X-12, which was also known as Pandora. Work on this ramjet-powered weapon had been initiated by the Guided Weapons Division of Bristol Aircraft prior to the formation of BAC in 1960. Proposals dated 3rd January 1963 showed a Vulcan carrying two X-12s on hefty pylons just outboard of the main wheels. Designed to meet OR.1182, this low-level stand-off bomb had a slim 50ft (15.2m) long fuselage of just 3ft 2in (98cm) diameter together with small delta wings 15ft (4.6m) long and 6ft (1.8m) span.



Avro Vulcan B 2 development with a fuselage spine for extra fuel and extended range (10.57).

The latter, and a semi-integrated BS.10-13 ramjet optimised for Mach 2.5, were mounted around the rear fuselage; a 28ft (8.5m) mid-fuselage section housed the fuel and the nose contained the warhead and guidance. At 20,000lb (9,072kg) weight, X-12's range would have been at least 1,000nm (1,852km); maximum ceiling was expected to be 70,000ft to 76,000ft (21,336m to 23,165m) and, initially, a cruising speed of Mach 4 had been planned. Projected in-service date was 1966.

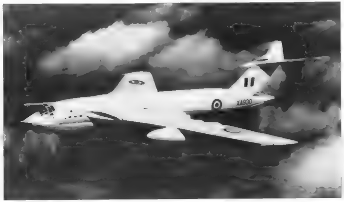
Another modification to the basic Vulcan suggested fitting two extra engines, cold Olympus 3s, on small nacelles two-thirds of the way out on the wing; this gave more thrust but also cut range and increased drag. An alternative was to bury them behind and below the four normal power units and, coupled with thinner outer wings of 5% t/c, it was predicted that this would increase drag rise Mach number by at least 0.02 from 0.87.

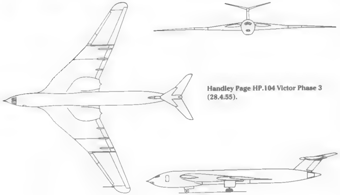
Finally, an October 1957 brochure suggested a way to keep Vulcan operational until the 1970s. This had enlarged intakes, a four-wheel undercarriage to allow all-up-weights up to 225,000lb (102,060kg) and the nose-wheel retracting vertically to make room for more weapons. Extra fuel and 17,250lb (76.7kN) Olympus Mk.200s gave a range of 5,000nm (9,260km). In addition to the basic 9,290gal (42,241lit), another 3,300gal (15,005lit) was housed in the bomb bay, 800gal (3,638lit) in a new dorsal spine and 1,250gal (5,684lit) in the wing. Take-off weight with a Blue Steel plus rear fuselage ECM gear was 221,047lb (100,267kg) and it was found desirable to provide fuel forward of the CofG to counter-balance the extra fuel in the integral wing tanks. Recent tunnel tests had shown that the existing Vulcan canopy was responsible for an undesirable drag increment so a revised shape was proposed. The opportunity was then taken to extend this new canopy aft and fair it into the existing dorsal fin so that extra fuel could be carried without an increase to frontal area or reduction in critical Mach number. This aircraft cruised at Mach 0.873.

Handley Page Victor Developments

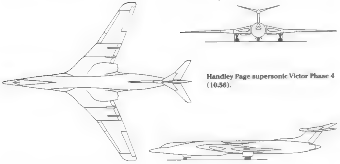
A Pathfinder high-speed target marker called the HP.98 was proposed in November 1951; this was aerodynamically and structurally identical to the HP.80 as built, complete with the same bomb bay, to allow it to easily revert to the standard bomber role. Normal take-off weight was estimated to be 145,000lb (65,772kg), overload 175,000lb (79,380kg) and cruise speed 576mph (926km/h). Radar-sighted remotely-controlled tail guns were fitted for low-level operations and the favoured power unit was the Conway 3 ahead of the Sapphire 4 and Olympus 3, but the Air Staff preferred the Valiant B Mk.2.

To satisfy the Air Staff's desire for more height over the target, Handley Page offered the Phase 2 and Phase 3 developments of spring 1955. Phase 2 had improved 14,000lb (62.2kN) Sapphire 9s and a span of 115ft (35.1m) while Phase 3 was pretty well an all-new design called HP.104. It possessed the same speed/range/bomb load as the B Mk.1 from which it was developed and could cruise over the target at 58,000ft (17,678m). Emphasis was placed on retaining the Mk.1's excellent flying qualities so no attempt was made to increase critical Mach number or the buffet boundary beyond the Victor prototype's limits. The improved cruising altitude was achieved through extra thrust and wing area, the most powerful engines currently envisaged (Olympus Ol.7s) being fitted. Standard Victor components would be used bar a new centre wing section to house the larger engines plus a longer rear fuselage for better missile stowage and to accommodate two 30ft (9.1m) sideways-looking aerials. Phase 2 and 3 were replaced in October by Phase 2A which became the Victor B Mk.2. The HP.114 Victor Phase 6 was a proposed missile carrier of August 1958.





Handley Page HP.104 Victor Phase 3 (28.4.55).



Handley Page supersonic Victor Phase 4 (10.56).

Handley Page Supersonic Victor

The Phase 4 Victor resulted from studies of the B Mk.1 and 2's supersonic capabilities. Applying area rule showed that the Victor closely approximated to the optimum shape for minimum compressibility drag in supersonic flight so the supersonic Phase 4 introduced a redesigned fuselage incorporating area rule and also reheat; the existing Mk.2 wings and tail were retained. With a take-off at 170,000lb (77,112kg), Phase 4 cruised at Mach 1.06 (702mph [1,130km/h]) at 65,000ft (19,812m) over the target whilst subsonically it had a range/load/height performance comparable to the Mk.2 with an optimum cruise speed of Mach 0.9 (593mph [954km/h] TAS). An intensive supersonic wind tunnel programme was proposed to check the aerodynamics, together with flight tests on a Mk.1.

HP's philosophy for the supersonic Victor indicated that by 1960-63 a subsonic bomber, flying over heavily defended areas at about 55,000ft (16,764m), might be unacceptably vulnerable to developments in defensive guided weapons. The successful development of air-to-ground missiles, enabling the V-bomber to avoid such areas, would provide a partial solution but possible setbacks to this policy included delays with these missiles, particularly in the problem of guidance. HP felt the Phase 4, with its ability to cruise at 65,000ft during a supersonic spurt, offered an effective insurance. It should be reasonably invulnerable over heavily defended areas during bomb dropping or reconnaissance and fully so when launching a guided missile over less heavily defended spots.

Its potential for rapid increases in altitude and speed from the cruise condition should also provide adequate protection against attack from defensive fighters. HP felt that the aircraft had a high degree of operational flexibility in speed, height, range and alternative roles, and provided an essential link in the development chain for the critical period 1960-66 when subsonic V-bombers might well be unacceptably vulnerable and fully supersonic types were not yet available. Normal internal fuel totalled 11,750gal (53,426lit). The Handley Page Association has suggested that Phase 4 could have been difficult since relatively little was then known about body waisting, while it also might have suffered severe drag.

This page, top: **Victor B Mk.1 XA930 in the all-white anti-flash colour scheme applied to most early V-bombers.**

Opposite page: **This is thought to be the Handley Page HP.114 Victor Phase 6 missile 'cruiser' (14.8.58). Note the enlarged air intakes.**

The engines specified for the V-bombers also first appeared in the late 1940s. Project design for the first Olympus was completed in 1949 and it was intended to be more powerful than any axial turbojet previously built in Britain. It was the first two-spool engine in the world having compound or twin-spool axial compressors in series, each driven by its own turbine, giving the advantage that the overall pressure-ratio could be higher than anything possible using a single-spool unit. Olympus was developed into many versions and power ratings and, when it appeared, Olympus 6 was to be the most advanced mark so far; its first bench test took place on 14th December 1954. Olympus 7 was first proposed in 1953 and by May 1958, with reheat and a convergent-divergent nozzle, it was giving 22,400lb (99.6kN) thrust for supersonic flight speeds.

The first RB.80 Conway of December 1948 was based on the RB.77 bypass engine noted in Chapter Two; RB.77 was essentially a brief study against the Avon. A bypass engine or turbofan is a turbojet where part of the air from the main compressor does not pass through the combustion chambers but, instead, rejoins the hot gases in the exhaust pipe. The bypass ratio (bpr) is calculated by dividing the volume of air not passing through the core by the volume that does. This allows a designer to make an engine that can run at a higher temperature and give more energy from the burnt fuel which then cuts fuel consumption and makes possible a lighter engine (there are penalties). The Conway could be thought of as having an oversize front compressor capable of passing more air than is required for combustion with the surplus bypassed around the outside of the combustion zone.

This formula was seen as ideal for a strategic bomber but on the Conway the bpr was eventually only about 0.6 maximum so, in the end, there was not that much difference to a pure turbojet. Initially, the RB.80 Conway was rated at 9,000lb (40kN) thrust but it was lighter than the Olympus. The two engines competed against one another throughout the 1950s and the reheated RCo.16R offered 31,360lb (139.4kN) thrust.

In November 1955 the Air Staff recommended that both Olympus and Conway should both be available for the V-bomber force as an insurance against failure of either and that the Conway should go into the Victor and Olympus into the Vulcan to fit in with their new wings. As of 25th June 1956 the Olympus held a lead over the Conway due to its higher recorded thrusts on the bench and longer running times. The basic bomber Olympus started at 16,000lb (71.1kN) and developed straightforwardly to the Ol.21 at 16,500lb+ (73.3+kN). The Conway began at 13,000lb (57.8kN) and developed straightforwardly to 16,500lb, but thereafter the Stage 4 (18,500lb [82.2kN]) was virtually a redesigned engine and there were doubts whether it would be interchangeable.

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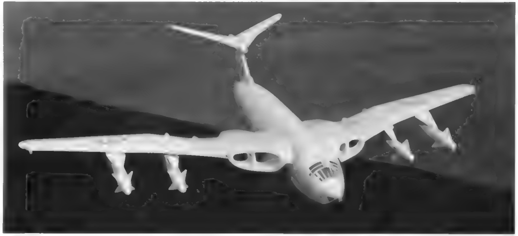
The detonation of atomic bombs over the Japanese cities of Hiroshima and Nagasaki in August 1945 brought the Second World War to an abrupt conclusion. They also marked the beginning of a profound shift in strategic thinking. During the immediate post-war period, advocates of air power in the USA and the UK perceived the unprecedented destructive power of atomic weapons as having changed the nature of war. Future conflicts, it was argued, would be fought from the outset using atomic weapons delivered over vast ranges; the possession of a nuclear arsenal became the hallmark of great power status.

Policy leaders in the UK were quick to grasp the implications of this new strategic environment. The Labour government which came into office in 1945 was committed to maintaining Britain's status as a major power and leading figures in the new government, including the Prime Minister, Clement Attlee, and the Foreign Secretary, Ernest Bevin, quickly came to regard the development of an independent atomic capability as vital to the UK's standing in the world. This conviction was reinforced by the passage of the McMahon Act by the US Congress on 6th November 1946, which banned all overseas access to US atomic secrets and brought to a halt wartime co-operation between the US and UK in this field. Convinced that Britain could no longer call upon the unqualified support of America, in January 1947 the Attlee government formally committed the UK to develop an atomic weapon; work also started on the new range of bombers capable of carrying such weapons over long ranges at high speeds and altitudes.

However, the development of atomic weapons and the means to deliver them continued to form only one element of the UK's defence posture. Britain remained committed to the defence of the Commonwealth and



the maintenance of Britain's position overseas and non-nuclear forces formed the core of that commitment. Additionally, the UK played an important role in the creation of an alliance structure to secure Europe in the face of a perceived Soviet threat, culminating with the signing of the North Atlantic Treaty in Washington on 4th April 1949. The outbreak of the Korean War in 1950 was feared by many to be the opening round of a Third World War and spurred the rapid expansion of the West's conventional forces. In February 1952, a NATO Council meeting in Lisbon agreed the force goals to be met by each member of the Alliance. Policy statement MC 14/1 outlined a plan for no fewer that 96 army divisions within 30 days of mobilisation, the target for the UK being set at between nine and ten regular and territorial divisions (later revised to nine regular and nine territorial divisions).

Changes in UK defence policy during the early 1950s were to move the UK independent deterrent to the forefront of British strategy. By the middle of 1952 it had become clear in London that the force goals embodied in MC 14/1 were completely unrealistic. From a British perspective, the demands of rearmament threatened to boost defence spending to 10% of the gross national product (GNP); such a crippling economic burden could not be sustained. Moreover, it was reasoned that in the event of an atomic war with the Soviet Union most of the West's conventional forces would be of little practical value. Meeting at Greenwich in the summer of 1952, the UK Chiefs of Staff hammered out a policy document (the 'Global Strategy Paper') that eschewed large numbers of expensive soldiers, sailors and airmen and their equipment. Deterrence lay at the heart of this approach. Soviet aggression would be met not with NATO forces, but with a nuclear attack on the Soviet homeland; all that would be required were sufficient ground, naval and air forces to keep the Russians in check while the atomic offensive launched by the West's strategic air forces, the US Air Force's Strategic Air Command (SAC) and Royal Air Force Bomber Command, would wreak havoc.

Although viewed initially in Washington as an attempt by the British to renege on their existing commitments, the Global Strategy Paper actually foreshadowed changes to American defence policy introduced by the Eisenhower administration in 1954 (the 'New Look'). In 1957, the concept of massive retaliation was formally accepted as the keystone of NATO's defensive posture in the form of policy document MC 14/2. In this new strategy, conventional forces were reduced to the role of a 'tripwire' to test Soviet intentions. Should NATO be faced with an all-out onslaught on the part of the USSR and its War-

Handley Page Victor B Mk.1 XA927, an early production machine.

saw Pact allies, NATO would rapidly resort to the arsenal of tactical and strategic nuclear weapons held by member states. The emergence of the Soviet nuclear arsenal during the 1950s led to the establishment of an uneasy status quo; by the end of that decade, it had become clear that any aggression by East or West could lead to a devastating exchange.

By the early 1960s, therefore, NATO had become a nuclear alliance. British nuclear forces played a vital role within this structure. A series of agreements concluded in 1957 enabled British and US nuclear strike planning to be closely co-ordinated, and from 31st December 1959 nuclear-armed Valiants were committed to the Supreme Allied Commander Europe (SACEUR) as the Tactical Bomber Force. Nevertheless, despite the intimate relationship between RAF Bomber Command and SAC, successive British governments remained committed to the concept of an independent deterrent under the sole control of the Prime Minister. One aspect of Britain's adherence to the concept of massive retaliation was the 1957 Defence White Paper. Military personnel levels were cut from 690,000 regulars and National Servicemen to an all-regular force of 375,000 men and women; conventional forces were

reduced, with emphasis being placed on weapons and equipment for use in a short 'spasm war' culminating in an all-out nuclear exchange.

Although offering both NATO and the Warsaw Pact every incentive to avoid a serious confrontation in Europe, by the early 1960s many in Washington had come to question the utility of massive retaliation. In the aftermath of confrontations with the Soviet Union in Berlin (1961) and Cuba (1962), the Kennedy and Johnson administrations began to search for options that would enable NATO to respond to a Soviet attack in Europe or elsewhere without plunging the world into nuclear war. Such an approach appeared rather less attractive from the European perspective. Despite Britain's small nuclear arsenal, NATO's defensive posture was almost wholly reliant upon extended deterrence – the notion that US strategic nuclear forces could deter a Soviet nuclear attack on European targets. However, any move on the part of the United States to find options short of an all-out nuclear exchange raised fears in the mind of many European theorists and politicians that the superpowers could fight a 'limited' war in Europe with conventional and nuclear weapons – a war which might be limited in global terms, but which would be as devastating for Europe (and particularly for Germany) as any worldwide conflict.

Despite European concerns, in 1967 NATO formally adopted the doctrine of 'flexible response' in the shape of MC 14/3. No longer was the defence of the NATO alliance dependent upon the early release of nuclear weapons. Rather, any Soviet thrust into Western Europe would be met by conventional forces; only in the event of a Soviet breakthrough, or in retaliation for the use of Soviet tactical nuclear weapons, would tactical nuclear weapons be used, with the US and British strategic nuclear arsenal preserved as a last resort. Flexible response was to form the core of NATO strategy throughout the 1970s and 1980s.

In their heyday the V-bombers were strategic weapons systems, designed to deliver nuclear weapons following a high-level penetration to the target. Development of the first atomic weapons to be used by the V-Force was undertaken by a team led by Dr William Penney, a leading member of the UK contingent at Los Alamos during the development of the first US atomic weapons (the Manhattan Project). Work progressed quickly, and on 3rd October 1952 the UK joined the 'atomic club' when a 25-kiloton (kt) atomic device was detonated below the River class frigate HMS *Plym*, then at anchor in the Monte Bello Islands off Australia's north-western coast (Operation *Hurricane*).

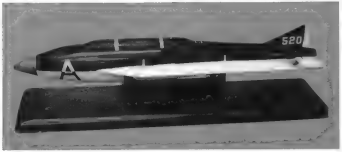
Subsequently, the RAF's initial atomic weapons were delivered to the Bomber Command Armament School at RAF Wittering in November 1953. Britain's initial atomic bomb was given the codename Blue Danube. Designed to operational requirement OR.1001, Blue Danube had a nominal yield of 20kt and was contained inside a casing derived from the 12,000lb 'Tallboy' bomb. Following extensive trials, the RAF demonstrated that it possessed a credible deterrent on 11th October 1956 when a Valiant of No 49 Squadron dropped a live Blue Danube Mk.1 round at Maralinga, Australia, one of four detonations carried at as part of Operation *Buffalo*. Only a small number of Blue Danube bombs were produced prior to withdrawal of the weapon from service in 1962.

The first tactical nuclear weapon to enter the UK arsenal was Red Beard. A fission bomb some 12ft (3.66m) long and weighing 2,000lb (907 kg), development of Red Beard commenced in 1954 in response to operational requirement OR.1127 for a tactical weapon to be carried by the RAF's Canberra force and by the Scimitars and later the Buccaneers of the Fleet Air Arm. Sources suggest that Red Beard had a variable yield of 5-20kt. Red Beard served with the RAF between 1961 and 1970 but modifications to the weapon to enable it to be safely stowed aboard the Royal Navy's aircraft carriers and carried externally by the Scimitar delayed delivery of the first examples to the Fleet Air Arm until 1962; the naval variant was phased out in 1971.

Development of Britain's first hydrogen weapon (employing the fusion rather than fission of atomic nuclei) commenced during the 1950s (the H-bomb was more powerful than an atom bomb). On 15th May 1957, a No 49 Squadron Valiant (XD818) operating from Christmas Island in the Pacific dropped a test round about a mile (1.6km) from the southern tip of Malden Island; although heralded as Britain's first H-bomb trial, it is now believed that this device may not have been a two-stage thermonuclear weapon. Subsequently, on 28th April 1958 Valiant XD825 of No 49 Squadron dropped a fully-fledged hydrogen bomb in the *Grapple Y* test.

The first example of an interim megaton weapon for the RAF, codenamed Violet Club, was delivered to the Bomber Command Armament School in March 1958. This bomb was rapidly superseded by Britain's first truly operational megaton-range thermonuclear weapon, Yellow Sun. Yellow Sun Mk.1 bombs, weighing 7,000lb (3,175kg), were introduced to arm the Vulcan B Mk.1 and Victor B Mk.1 in

A Boeing B-52H global ballistic missile bomber is seen carrying inert Skybolt rounds during the weapon's flight test programme.



Model of a momentum bomb.
Bristol Aero Collection

1960. Later, the Yellow Sun Mk.2 was introduced weighing 7,250lb (3,289kg) and with a yield of 1mt; Yellow Sun formed the backbone of the RAF's free-fall nuclear arsenal during the 1960s.

Not all of the air-delivered nuclear weapons carried by RAF bombers during the 1960s were of British origin. Following the co-ordination of British and US strike planning in 1957, from 1958 a number of US nuclear bombs were made available to RAF Bomber Command (and subsequently to the RAF Canberra squadrons in Germany) under a programme codenamed Project 'E'. When carried by RAF aircraft, these weapons remained under USAF control. Bombs provided to the RAF included the 6,000lb (2,722kg) Mk.5 and the 1,900lb (862kg) Mk.28 for the V-Force; the 1,650lb (748kg) Mk.7 for the Canberra; and the 2,100lb (953kg) Mk.43, which was carried by both the Valiant and the Canberra. Bomber Command's Vulcan and Victor squadrons ceased to employ Project 'E' weapons in March 1962. US bombs continued to be used in conjunction with the Valiants of the Tactical Bomber Force until the aircraft was withdrawn from service in 1965, and by RAF Germany until 1969.

The first atomic and hydrogen bombs used by the RAF were free-fall weapons. However, the rapid improvement of Soviet air defences during the 1950s spurred the development of new weapons that would not require the carrier to pass over the target. An early attempt to afford RAF bombers with a weapon offering both a stand-off capability and increased accuracy came in the form of the Vickers Blue Boar TV-guided glide bomb, development of which commenced in 1947 to OR.1059. However, Blue Boar was limited to the range of its guidance system and was cancelled in 1954 to be replaced by the much more ambitious Avro Blue Steel air-launched guided weapon. Developed to meet AST/OR.1132 and specification UB.198, Blue Steel was designed to be carried under the fuselage of the Vulcan and Victor. The result was a large weapon which weighed 14,640lb (6,641kg), was 35ft (10.67m) long and had a span of 13ft (3.96m). The RAF's first Vulcan/Blue Steel squadron, No617, achieved an emergency operational capability in September 1962 and became fully operational with the missile in the following February.

Blue Steel could be launched using a variety of attack profiles. Although the maximum range of the missile was in the region of 200 miles (322km) at Mach 0.8-0.9, a high-level launch might involve release from 50,000ft (15,240m) some 100nm (185km) from the target. After release, its 16,000lb (71.1kN) Armstrong Siddeley Stentor HTP/kerosene engine would accelerate the missile to a speed of Mach 2.5 at 70,000ft (21,336m). A small sustainer would then propel it for the remainder of its four-minute flight, at the end of which it would pitch over to dive at an angle of 40° and a speed of Mach 1.5-1.8 towards the detonation point. Blue Steel carried the Red Snow megaton-range warhead, the operational requirement for which (OR.1141) had been issued in January 1956.

During the early 1960s it became clear that Blue Steel's stand-off range would not be sufficient to guarantee that Victors and Vulcans could reach their launch positions at high level before falling foul of Soviet fighters and surface-to-air missiles. In response to this threat, following a successful series of low-level firing trials at Woomera the Blue Steel force was switched from high to low level in 1964. In this attack profile, release ranges were reduced to 25 to 30 miles (40km to 48km); the missile would then zoom climb to an altitude of 17,000ft (5,182m) before diving onto the target. The last RAF squadron to be equipped with Blue Steel (No617) flew its last sortie with this weapon on 21st December 1970.

In 1957 work commenced on a long-range, ramjet-powered version of Blue Steel to meet operational requirement OR.1159 and specification UB.200. Blue Steel Mk.2 was expected to weigh in at between 22,000lb and 25,000lb (9,979kg and 11,340kg) and to enter service in 1969. Development was cancelled on 1st January 1960 in favour of the Douglas Skybolt air-launched ballistic missile, which in turn was cancelled by the Kennedy administration (as described earlier). Prior to Skybolt's entry into RAF service, it was projected that Blue Steel would be replaced in 1963-64 by a powered bomb with a range of 1,000nm (1,825km). An operational requirement, this weapon (OR.1149) was prepared by the Air Staff and tenders were submitted by several companies which included Avro's W.107 and Handley Page's HP.106.

As well as the OR.1182 weapons already described, other options considered by the Air Staff for the V-Force included the US Hound Dog missile, enhanced versions of Blue Steel Mk.1, an unpowered momentum bomb or new low-level lay-down bombs; alternatively, the V-Force could be replaced by Minuteman inter-continental ballistic missiles. The momentum bomb was proposed in 1962 for carriage by V-bombers, Buccaneers or TSR.2 and would have had a range of 6 miles (9.7km) at low level, 40 miles (64km) at height; the primary version would be nuclear but there would also be a high-explosive version. Configurations were analysed with either folding wings and a canard or a slim wing running alongside most of the body's length; the latter appeared to be the more promising but the weapon was abandoned because it was expected to fly too slowly to make an effective attack. In the event, the decision by the British government to procure the Polaris missile system signalled the end of the manned bomber as the UK's primary strategic deterrent system; continued development of the X-12 Pandora as a hedge against the failure of Polaris was rejected by the Air Staff at the end of 1962.

When discussing nuclear weapon carriage, early bomber brochures often refer to a 'special bomb', Target Marker Bomb or other discreet terms. This was because the aircraft manufacturers had yet to receive any concrete information about the weapon. For example, the projects to B.35/46 described in Chapter Two were intended to take a 10,000lb (4,536kg) 'special bomb', which was actually Blue Danube; for authenticity this brochure description has been retained in the data tables. Such bogus names were euphemisms to help conceal the atomic weapons' existence but they also made it easier to discuss them.

Scale Model Aircraft Projects – Estimated Data

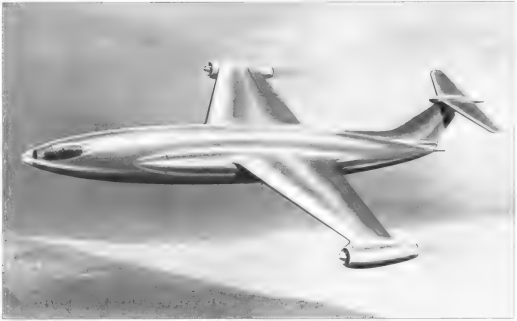
Project	Span ft in (m)	Length ft in (m)	Wing Area ft² (m²)	t/c %	All-Up-Weight lb (kg)	Powerplant Thrust lb (kN)	Cruise Speed mph (km/h) Height ft (m)	Weapon Load lb (kg)
Bristol Type 174	45 9 (13.9)	47 2 (14.4)	435 (40.5)	12.5	26,000 (11,749)	1 x RR Nene 5,500 (24.4)	High Subsonic	None
Bristol Type 176	33 0 (10.1)	46 0 (14.0)	217 (20.2)	?	12,200 (5,534)	1 x RR Avon 6,500 (28.9)	Mach 0.92	None
H Page HP.88 (Flown)	40 0 (12.2)	39 10 (12.1)	286 (26.6)	14 root 5 tip	13,197 (5,986)	1 x Nene R.N.2 5,000 (22.2)	cMach 0.85	None
Avro 707 (at 6.4.48)	33 0 (10.1)	30 0 (9.1)	not given	not given	7,972 (3,616)	1 x RR Derwent	400 (644) up to 10,000 (3,048)	None
Avro 710 (at 6.4.48)	49 0 (14.9)	44 9 (13.6)	not given	not given	19,651 (8,914)	2 x Avon 6,500 (28.9)	575 (925) up to 60,000 (18,288)	None
Avro 707 (VX784 flown)	33 0 (10.1)	40 2 (12.2)	366.5 (34.1)	not given	8,600 (3,901)	1 x Derwent 5 3,500 (15.6)	403 (648)	None

V-Bomber Developments – Estimated Data

Project	Span ft in (m)	Length ft in (m)	Wing Area ft² (m²)	t/c %	All-Up-Weight lb (kg)	Powerplant Thrust lb (kN)	Cruise Speed mph (km/h) Height ft (m)	Weapon Load lb (kg)
Vickers Valiant B Mk.2 Pathfinder (Flown)	114 4 (34.9)	108 3 (33.0)	?	12 to 8	196,492 (89,129)	4 x Avon RA.14 10,000 (44.4)	552 (888) at sea level	1 x 10,000 (4,536), 2 x 5,000 (2,268), 21 x 1,000 (454), 1 x 10,000 Blue Boar or 2 x 5,000 Blue Boar
Vickers Low-Level Valiant	81 0 (24.7)	124 6 (37.9)	2,150 (200.0)	Not given	306,000 (138,802)	See text	652 (1,049) between 2,500 (762) and 7,500 (2,286)	1 x 10,000 (4,536) or various smaller
Vickers Supersonic Valiant	85 0 (25.9)	130 0 (39.6)	2,000 (186.0)	5	177,000 (80,287) (207,000 [93,895] with tanks)	4 x Conway Co.3	1,013 (1,630) Mach 1 33 at sea level. 979 (1,575) Mach 1 48 at 36,000 (10,973)	1 x 10,000 (4,536) or various smaller
Vickers Valiant Mk.3	108 9 (33.1)	108 2 (33.0)	2,270 (211 1)	12 root 8.45 tip	188,541 (85,522)	4 x Conway 11,500 (51.1)	501 (806) at sea level. 616 (991) at 20,000 (6,096)	10,000 (4,536) normal, up to 41,000 (18,598) with reduced fuel
Avro Vulcan B Mk.2 (Flown)	111 0 (33.8)	105 6 (32.2)	3,964 (368.6)	10 root 5 tip	204,000 (92,534)	4 x Olympus 201 17,000 (75.6)	640 (1,030) at height	1 x Blue Steel or 21 x 1,000 (454)
Handley Page Victor B Mk.2 (Flown)	120 0 (36.6)	114 11 (35.0)	2,597 (241.5)	?	233,000 (105,689)	4 x Conway 103 17,250 (76.7)	645 (1,038) at 40,000 (12,192)	1 x Blue Steel or 35 x 1,000 (454)
Handley Page HP.104	137 0 (41.7)	136 0 (41.5)	3,267 (303.8)	15 root 10 1st kink 8 2nd kink 5 7 tip	210,000 (95,256)	4 x Olympus Ol.7 17,160 (76.3)	576 (926) at height	1 x 10,000 (4,536) special, 1 x 12,000 (5,443) Tallboy or 1 x 22,000 (9,979) Grand Slam
Handley Page Supersonic Victor	120 0 (36.6)	145 0 (44 2)	2,672 (248.5)	15 root 10 kink 8 kink 5.6 tip	long-range 200,000 (90,720) medium range 170,000 (77,112)	4 x Conway 31 20,000 (88.9) dry, reheat gave 4,000 (17.8) at 60,000 (18,288) and Mach 1.05	Mach 1 1 at 36,000 (10,973)	1 x 7,000 (3,175) conventional store, 1 x 2,000 (907) nuclear store or 1 x 15,000 (6,804) stand-off weapon

Chapter Four

Low-Level Introduction



Artist's impression of the Short P.D.9 in flight. The intakes for the fuselage-mounted Sapphires are faired over for cruising flight. Shorts

Initial Low-Level Bomber Studies: 1952 to 1954

During the Second World War, much the greater part of the heavy bombing campaign undertaken over Germany by the RAF and USAAF was made at height, except for selected operations such as the Dams raid. That particular operation took place in moonlight requiring flight to and from the target at 200ft (61m) or less to help avoid detection by radar and attack by fighters and flak. Such practice would become essential within the next fifteen to twenty years. The greater speeds made available by jet propulsion allowed high-level bombing to continue for a period after the end of hostilities, but eventually the advent of combined and co-ordinated radar, surface-to-air missiles and interceptor fighters suddenly made this a far more difficult and dangerous proposition. A solution was high-speed low-level penetration but this produced much greater loads and stresses on an airframe with a consequent reduction in its fatigue life.

The argument for a Low-Altitude Bomber (LAB) was first mooted by the Air Staff on 26th June 1951, two and a half years before the first flight of a production Valiant (all the V-bombers were designed for high-level bombing). Current bomber developments saw a restriction in operations for these machines, except at short range, to a comparatively narrow height band from 40,000ft (12,192m) upwards, casting away the full 3-dimensional advantage hitherto available to the attacker in air war. From early 1952 until September 1954, the Air Ministry and MoS considered the desirability of developing a high-speed low-altitude bomber to supplement the V-bombers. The V-force had two potential limitations – it was expected that the enemy (the Soviet Union) would soon concentrate his defensive effort on the band above 40,000ft (12,192m) while, at the same time, the force would become increasingly vulnerable to ground-launched missiles as they were developed. A low-altitude bomber would not suffer these limitations and its use with the V-bombers would force the enemy to considerably extend his defence effort.

A LAB Working Party set up in December 1952 concluded that for a maximum range of 4,500nm (8,339km), an aircraft of about 200,000lb (90,718kg) would be required with a very high wing loading of up to 300lb/ft^2 (131kg/m^2). The weapons, electronics and engines needed were all examined closely (a minimum of three engines was felt necessary for agreeable failure safety) but the overriding factor governing introduction of a LAB into service was the development of a winged stand-off missile. This dictated a service entry of 1962/63 which accordingly became the target for the MoS. In-flight refuelling was felt to be particularly desirable and a 30mm Aden cannon in a rear turret was, for a period, a clear requirement (manned if possible but remotely controlled if the former gave an excessive weight penalty). Long before the Working Party had completed its studies an Operational Requirement was raised and it was envisaged that design to the eventual OR.324 would entail as great an advance in aircraft design as had been necessary to produce the V-bombers.

B.126T

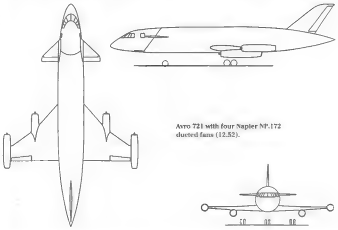
Specification B.126T and the accompanying OR.314 were approved on 5th May 1952 (OR.314 was later superseded by OR.324). Many points were left open so that designers could forward their opinions; for example, either turboprops using supersonic propellers or turbojets could be used though it was acknowledged that no such propeller was then under development. Investigations would consider new problems such as low-altitude navigation, low-level bombing and the physiological effects arising from long periods at low altitude and high speed. The machine's role was to attack targets deep in enemy territory from low level, either as a diversion and complement to high-altitude operations or, should the latter's losses become prohibitive, as the main bomber effort. The whole operation was to be carried out at low level to reduce radar warning of approach and minimise the effect of guided missiles, interceptors and anti-aircraft gunfire.

A 10,000lb (4,536kg) bomb load would be taken to a target 2,500nm (4,633km) away, but if much development time could be saved, a minimum operational radius of 1,500nm (2,780km) would be acceptable initially. Operational height was to be 500ft (152m) or less for 80% of the outward journey and cruising speed at least Mach 0.85, together with short bursts of higher speed for evasion if possible. This was later quantified as Mach 0.95 for 10 minutes over the target. In-flight refuelling was requested and external bomb stowage was acceptable. The bomb was originally described as a propelled, controlled air-to-surface missile to be released between Mach 0.85 and the aircraft's maximum. The avionics included both forward and sideways-looking radars. On 4th June 1952, Avro, Bristol, de Havilland, Folland, Handley Page and Shorts were all asked to supply a design study and four had submitted proposals by the end of December 1952.

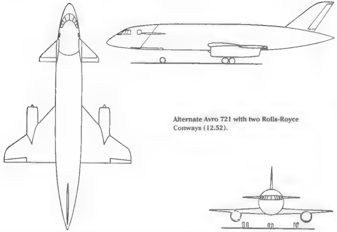
Avro 721

Avro felt this aircraft completely fulfilled B.126 and its construction could proceed at once without the need for fundamental aerodynamic or structural research. It utilised Avro's growing experience with delta wings following the Vulcan and 707 family, but looked more like a short-haul airliner; an outstanding feature was its very low aerodynamic drag achieved essentially by a reduced wing area. Each component was designed for minimum drag; for example a fuselage of circular section and moderate fineness ratio gave the smallest surface area necessary to enclose the three crew members, an atom bomb,

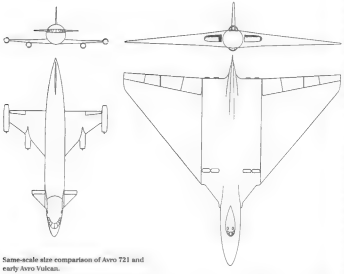
Artist's impression of the Avro 721.



Avro 721 with four Napier NP.172 ducted fans (12.52).



Alternate Avro 721 with two Rolls-Royce Conways (12.52).



Same-scale size comparison of Avro 721 and early Avro Vulcan.

operating equipment and most of the huge volume of fuel.

Described as a tail-first aircraft, the 721 had a small wing and large fuselage. Outer wing t/c ratio was 6% rising to 7% at the kink and 11% at the body-side while, at the same time, the maximum thickness was moved forward. This was an extension of the method of controlling the effective sweepback at high subsonic Mach numbers developed by RAE and used on the Vulcan. Critical Mach number was 0.9. A straight trailing edge gave maximum lift from the Fowler flaps, supplemented by a split flap under the fuselage. An advantage of the delta was inherent stiffness, essential in the high air speeds for which the 721 was designed, permitting the spars to be at right angles to the line of flight; this removed the weight and complexity of cranked and jointed spars. The wing structure was continuous across the fuselage and contained a 600gal (2,728lit) fuel tank while the main wheels retracted into the forward wing. The fuselage housed fuel tanks of 11,300gal (51,371lit) total capacity.

Following a comprehensive study of various layouts, the 'tailplane' was placed ahead of the wing which helped to increase lift on take-off and landing, improve tail efficiency and therefore reduce tail size and drag, and accommodate trim changes. It was particularly suited to carrying the bomb in the extreme tail of the fuselage. Type 721 was intimately bound up with the bomb's size and shape, the methods of its release and travel to target. After studying possible bombing techniques to allow the 721 to be at a safe distance when the bomb exploded, Avro felt this was best achieved by using a winged rocket-propelled weapon. Dropping the weapon at high speeds from a bomb bay was deemed impossible so it was stored in the rear fuselage with ejection backwards through opening doors; this permitted carriage with minimal loss of performance and disturbance on release. Other types of bomb could be carried here, or externally below the fuselage (the rear fuselage also contained built-in rocket motors for take-off assistance). Ejecting the bomb from a mid-fuselage bay had been studied but this reduced range. There were no defensive guns.

A ducted-fan engine was necessary for good specific fuel consumption (1.0lb/lb/hr under these conditions rather than the current best of 1.1lb/lb/hr). Specific schemes had been prepared by Napier and Rolls-Royce but, as proposed, the Type 721 had four 5,440lb (24.2kN) Napier NP.172 ducted fans which gave enough power for flight to be sustained in the target area without one engine. Another advantage was that one or two units could be stopped under reduced speed conditions to conserve fuel. Alternatively the 721 could use two 11,500lb (51.2kN) Rolls-Royce Conways modified to give a greater bypass ratio, which reduced the span by 3ft (0.9m), but the Conway lacked sufficient power for flight under engine cut conditions except at very light weights. In truth a unit of about 12,700lb (56.5kN) was required so a study was made using two Napier NP.172s scaled up by a factor of 2.34 to the required 12,700lb, but even this 'Napier high thrust engine' gave problems for single-engine flight.

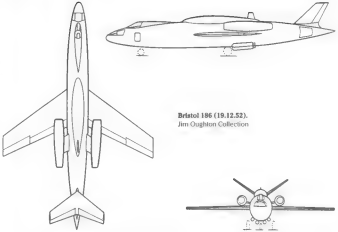
The Type 721 had a high wing loading and, consequently, a normal unassisted take-off was impossible except at very light weight. To carry enough fuel for a 3,350nm (6,208km) range, take-off could be rocket assisted or at minimum weight followed by flight refuelling, hence the two 10,000lb (44.5kN) rockets mounted in the rear fuselage. For a 5,500nm (10,193km) range (20% over spec.), take-off would have to be with the fuel for a 3,350nm sortie and RATO, followed by air refuelling. Take-off weight for the 5,500nm mission was 90,400lb (41,005kg). For a full weight departure, a proposal was included for mounting four 20,000lb (89kN) rocket motors, developed from the Armstrong Siddeley Screamer or de Havilland Spectre, beneath the fuselage and inclined 30° down. An alternative envisaged the use of a 'slip-plane' which was actually another aircraft powered by four jet engines to supply additional thrust and wing area. The 721 and the slip-plane would take-off as a composite aircraft before separating at a safe height.

An appreciation of the 721 could be gained by comparing it to the current Vulcan. With the same bomb load, the latter flew at Mach 0.87 and 50,000ft (15,240m) for a range of 5,000nm (9,266km). Air density at sea level is six times that at 50,000ft and to obtain a reasonable value of air miles per gallon of fuel at the same true air speed, the 721's drag had to be correspondingly reduced. Although the Mach numbers of the two aircraft were similar, the greater temperature at sea level resulted in a further 69mph (111km/h) air speed. Maximum level speed for the 721 at 80,000lb (36,287g) was about Mach 0.94 at 15,000ft (4,572m) with design dive speed reaching Mach 1.0. Reheat would push level speed up to Mach 0.97 but needed more fuel and hence a larger and heavier aircraft.

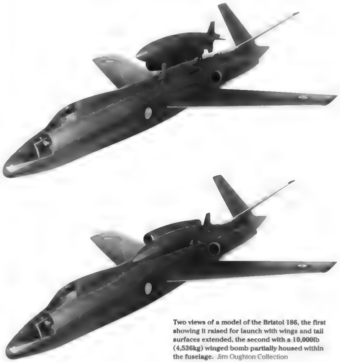
Bristol Type 186

This offered the unusual approach of engines mounted on struts above and to the side of the rear fuselage. The multi-spar wing's take-off loading was 136lb/ft² (61.1kg/m²), at all-up-weight 250lb/ft² (112.2kg/m²), and the wing housed 2,150gal (9,774lit) of fuel. Hydraulically operated single-slotted trailing-edge flaps were provided together with unbalanced ailerons which were power operated through duplicate units. A V-tail with 35° of dihedral was chosen to minimise any disturbance from bomb release and this was adjustable in flight through 6°. When moved in the same direction the tail's trailing-edge flaps acted as the elevators; moving in opposite directions they became the rudders.

The body had an elliptical cross-section and excepting cut-outs for the bomb-cell, undercarriage units and wing, contained



Bristol 186 (19.12.52).
Jim Oughton Collection



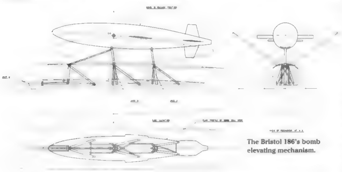
Two views of a model of the Bristol 186, the first showing it raised for launch with wings and tail surfaces extended, the second with a 10,000lb (4,536kg) winged bomb partially housed within the fuselage. Jim Oughton Collection

14,500gal (64,613lit) of fuel from aft of the cockpit to the tailplane front spar. Construction was conventional using light alloy skins, stringers and frames. The undercarriage was a normal tricycle with all units folding forward and upward into the body and the crew comprised a pilot and navigator/bomber, with the latter housed in the extreme nose; an extra crewman was provisionally proposed. The engine pods housed two 11,000lb (48.9kN) modified Bristol Olympus 101s while around the lower fuselage just behind the main landing gear were four RATO motors which would give a total of 14,700lb (65.4kN) extra thrust for 32 seconds.

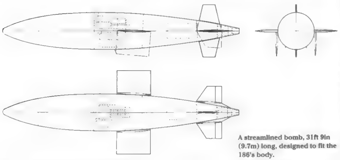
The single streamlined 10,000lb (4,536kg) bomb was carried half buried in a recess on the top fuselage, above the wing roots between and slightly forward of the engine pods. With its wings and horizontal tail surfaces folded down, this gave a relatively smooth compound shape which reduced drag during the flight to the target area. For release it was raised on a support until the folded wings were clear of the parent aircraft; these were then unfolded as the propulsion unit was started up. The support then extended further out to present the bomb to the airstream at an attitude suitable for release; as this happened a door would cover the now empty stowage slot in the fuselage.

The bomb's form was an approximation of the specified weapon but suited to fit the 186's body; diameter was 60in (152.4cm), length 383in (973cm) and it had thin low aspect ratio constant chord wings. Control in flight was provided by a cruciform tail with the upper vertical surface exposed during the whole flight. After launch, it was assumed that free flight would last about 60 seconds with propulsion provided by a rocket in the rear body which maintained speed between Mach 0.8 and 0.9. The guidance system would be fed with information up to release and manoeuvres after release might involve turns, climbs and dives at up to 3g.

Since flight refuelling was felt necessary, take-off weight was less than all-up-weight; the undercarriage was designed for a take-off maximum of 97,000lb (43,998kg). Gross weight was 180,000lb (81,647kg) of which 128,000lb (58,060kg) was fuel. Still air range with the bomb dropped at half range was 5,000nm (9,266km) at sea level and 5,170nm (9,581km) at 1,000ft (305m), cruise speed was Mach 0.85 which at 1,000ft was 645mph (1,038m/h). A 30mm cannon was provisionally mounted in the rear fuselage with a defence radar pod in the tail root but, long term, no defensive armament was planned.



The Bristol 186's bomb elevating mechanism.



A streamlined bomb, 31ft 9in (9.7m) long, designed to fit the 186's body.

Handley Page HP.99

Handley Page completed its brochure in January 1953 and reported that it was possible to design a small aircraft to meet the short-range requirement (1,500nm [2,780km] radius), but it needed to carry very large drop tanks to reach the 2,500nm (4,633km) limit; the resultant wing loading then became too high to be practicable. These conclusions had led to the adoption of a larger aircraft able to carry a substantial bomb load over a range approaching 4,500nm (8,339km) at sea level. Reductions in engine fuel consumption and fully laden weight would increase this to 5,500nm (10,193km).

Long range at low altitude demanded that aircraft drag must be kept to a minimum and three methods for reducing drag had been explored:

a. Reducing wing area at the expense of wing loading,
b. Employing boundary layer control to improve propulsive efficiency,
c. Reducing wetted area in flight.

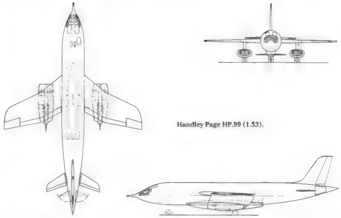
For (b) a study was made using gas turbines to apply suction to the whole surface of the aircraft (wings, tail and fuselage) which was ejected aft at approximate flight speed. This gave an increase in propulsive efficiency and a consequent saving of some 15% of all-up-weight but, although providing the most efficient design, it would have to be a long-term project. Method (c) involved retractable or jettisonable wings, jettisonable tanks (both attached to and towed behind the aircraft) and external and towed bomb containers, but the resulting complexity and extended development time gave no saving in cost.

The chosen wing plan followed an examination of many alternatives; it showed good landing and stalling characteristics, a low rate of descent in an engine-out situation and a satisfactory rate of climb after a baulked landing. It was a compromise to allow a cruise of Mach 0.85 with an aspect ratio high enough to ensure ample reserve power on the approach without penalising low-speed control at the stall. A satisfactory performance had been confirmed in the wind tunnel. An aircraft designed for supersonic bursts had been considered and rejected because the severe restrictions imposed by supersonic flight prejudiced its high subsonic performance and greatly restricted its range, bomb and missile capacity. Therefore HP.99 was designed for cruise at high subsonic speed (Mach 0.85) although future investigations were planned using wings designed for Mach 0.9 cruise. The maximum Mach 0.92 at sea level was limited to five minutes.

HP.99 had three crew, Handley Page noting that fatigue would be reduced by having two pilot-navigators and one radio navigator. Fatigue from the bumps usually associated with high-speed low-altitude flying would be moderated by the aircraft's high wing loading which would nullify the effects of gusts. HP.99 had a total fuel capacity of 22,700gal (103,196lit) and a flight refuel probe was fitted in the nose. Four Avon RA.14s were installed in pairs in pods beneath the wing; this was in preference to buried engines which HP felt would have had a relatively large adverse effect on the wing characteristics because of the surface's small area and thin root-section. The undercarriage main gears were mounted in the engine pods.

Maximum take-off weight using water injection and rocket boost was 160,000lb (72,575kg) while maximum laden weight following a mid-air transfer of 13,000gal (59,099lit) of fuel was 260,000lb (117,934g). At 260,000lb, complete with a single 10,000lb (4,536kg) bomb, range for Mach 0.85 at sea level throughout was 4,440nm (8,228km); with 80% of the mission flown at sea level and 20% at optimum height this figure became 5,020nm (9,303km) and for the entire flight performed at optimum height it was 7,350nm (13,621km). At 160,000lb weight, equivalent ranges were 1,925nm, 2,405nm and 4,450nm (3,567km, 4,457km and 8,247km). The wing loading for a normal take-off was $145lb/ft^2$ ($65.1kg/m^2$).

To achieve effective results without the aircraft being endangered, bombing at low altitude required the solving of many problems. It would be necessary to retard the bomb by parachute after dropping or to replace it by a powered self-controlled winged missile which, after release, would fly to the target. The missile could be mounted either above or below the aircraft but the lower position was chosen for the HP.99 to make it available for normal bombing operations if required. The winged missile was installed by replacing the non-structural sides of the bomb bay with suitable fairings and ample space was available for the powered ejection of bombs. Very little equipment existed for navigating a bomber at low altitude so, for daylight operations, it was assumed that the main approach for the HP.99 would be visual observation matched with synchronised moving maps.



Handley Page HP.99 (1.53).

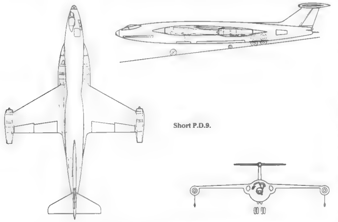
Short P.D.9

Shorts' preliminary studies showed that the biggest problem of low-altitude bombing was to achieve the required range without going to an unreasonably high weight and wing loading. Four ideas were reviewed – the 'straightforward approach' with delta wing and four Olympus, two mounted forward and two aft; a similar short-range version with three Sapphire Sa.3s; an 'aero-isoclinic wing' design and a curious 'partly expendable aircraft' which progressively reduced its weight and drag in flight as fuel was consumed. The idea was to shed the undercarriage after take-off (flexible deck landing), shed wing area and perhaps some of the engines as weight decreased and finally the bomb cell with its fuselage after dropping the bomb. A relatively small piloted aircraft formed the upper component of a composite, the lower part carried the bomb load and was jettisoned after the drop to leave the piloted machine to return to base.

For its P.D.9 design Shorts concluded that it was theoretically possible to build a twin-engined aircraft to fulfil the specification but, for safety, felt that nothing less than four engines would be acceptable. The result was a conventional design with moderate sweepback and a tail which the company thought represented a straightforward and practical solution from both constructional and operational aspects, with minimum time required before service entry. P.D.9 was orthodox in appearance and embodied no major structural or aerodynamic problems. The ailerons were power operated, the all-moving tail was set high on top of the fin and the undercarriage comprised two main units in tandem, both retracting into the fuselage, with tip outriggers which folded into the engine pods. The front main leg had four wheels on a single axle, the rear four wheels on a bogie.

The two-man crew comprised pilot and navigator with the pilot station offset to port under a canopy modelled along fighter lines to keep size to a minimum. This feature had an incidental but important advantage, namely it would be less vulnerable to bird impacts which, although a known hazard, were now expected to assume greater importance on low-flying aeroplanes. The exact nature of the equipment to be installed in terms of radar and navigation was still unknown. Excepting the equipment areas, weapon and undercarriage bays, the fuselage was filled almost entirely with 16,280gal (74,010lit) of fuel. Another 2,470gal (11,229lit) were housed in the wings and a further 'jettisonable' 15,000gal (68,191lit) made for a total fuel load of 33,750gal (153,431lit).

The bomb cell was arranged within the fuselage underside to provide stowage for a 'small size' 10,000lb (4,536kg) bomb delivered by toss-bombing. A 'large' version, or several normal bombs, could be accommodated instead, the former replacing some fuel, and a radar-controlled cannon was mounted in the extreme tail for defence. Four 11,000lb (48.9kN) Armstrong Siddeley Sapphire Sa.7s were fitted, two in wing tip pods and two more adjacent to the fuselage sides under and ahead of the wing. The latter were



Short P.D.9.

to be used primarily for take-off only, being shut down and faired over once airborne to leave the tip-mounted units for cruising. In addition, two 10,000lb (44.5kN) retractable rocket motors were installed in the sides of the rear fuselage to assist take-off.

Maximum take-off weight was 144,000lb (65,317kg); operational all-up-weight for a still air range of 3,750nm (6,949km) (= a 1,500nm [2,780km] radius of action) was 195,000lb (88,450kg), so reaching maximum weight again required flight refuelling once the aircraft was airborne. The range was achieved by cruising at Mach 0.85 and 500ft (152m); the full operational radius of 2,500nm (4,633km) could not be reached in this configuration. Top speed using the extra 20,000lb (89.0kN) rocket thrust was 737mph (1,186km/h), dropping to 715mph (1,151km/h) on jet power alone. Wing loading with full fuel was 195lb/ft^2 (87.6kg/m^2).

After considering its preliminary studies, Shorts envisaged a stage-by-stage approach to reach B.126 in full. P.D.9 would be Stage 1. Stage 2 would increase all-up-weight to 230,000lb (104,326g) by adding fuel for a radius of 1,880nm (3,484km); this depended on the development of take-off techniques at high wing loading and the availability of more powerful rockets. Stage 3 deleted the undercarriage and filled the bays with additional fuel for a 2,070nm (3,836km) range (the tandem wheels made this possible); take-off used a jettisonable undercarriage or a 'soft trough' catapult with landing on a flexible deck. Finally, Stage 4 envisaged the installation of new jet or ducted-fan engines specifically designed for low-altitude operation – with a small increase in all-up-weight, the aircraft could achieve the full operational radius of 2,500nm (4,633km). Shorts felt the big advantage was that Stage 1 involved a conventional machine (P.D.9) which relied on existing RATO and flight refuelling techniques so that it could be built immediately.

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The principle objective for these studies was to obtain and assess different approaches before putting together a draft Operational Requirement, which in due course appeared as OR.324. In February 1953 RAE Farnborough produced Technical Note Aero 2193 *Problem of the Low Altitude, High Speed, Long Range Bomber* which was based on B.126T and highlighted two main difficulties:

i. The functions of the low-altitude requirement – defence, bombing, vision.
ii. Situations where high wing loadings were an important factor – take-off and landing and control behaviour in gusts.

The conclusions were that the many and varied problems could be solved. The perception that gust effects made the aircraft unflyable over long periods was examined using present knowledge (could pilots tolerate it?) and the report recommended that research into gust alleviation should continue as a high priority.

On 9th July 1953, the Ministry's V H E Cole reported on some of the project's political aspects. To begin, it had been assumed throughout the Ministry and Air Staff that work would start with an initial outlay of £4m and was to be tackled by just one company only, with no question of an insurance. Two companies undertaking the project had been a possibility but the hallowed practice of many years, to insure top priority projects on which the whole offensive power of the RAF would depend, was not needed for the low-altitude medium bomber (the practice usually took the form of a fairly conventional development proceeding in parallel with an advanced or unconventional development).

This bomber was viewed as a complementary weapon system and, although very important, was not one on which the Air Staff were staking their all. If sufficient basic knowledge existed for the project to proceed without delay then the insurance policy was unnecessary, particularly as the Air Staff's emphasis on speed suggested waiting to make a choice from competing developments was a luxury that could not be afforded. In addition, the present financial circumstances made the doubling-up of provisional estimates to allow two companies to proceed difficult to justify.

For most preceding programmes, the accepted view was that design study contracts were issued by the MoS with a view to writing a specification, which was then put out to an industry tender design competition. The Ministry was not necessarily bound by this course for the LAB but it was over 12 months since design studies had been requested and a point had now been reached where the traditional bomber companies were running out of work; Cole felt that other companies might like to tender designs. After all, LAB development would take six to seven years and possibly longer if it embodied a new engine such as the Armstrong Siddeley Project X, a proposed 15,000lb (66.7kN) unit.

Cole also noted that the Ministry believed it was essential for one team to handle design of the aircraft and the guided bomb it was to carry, which limited the number of companies that could be considered. Both Avro and Handley Page were seeking work and the former was particularly anxious to enter the sphere of guided weapons. There was every indication that Bristol had its hands full with civil and guided weapon commitments and the company was understood to be likely to seek outside help if the Canadians required the Britannia airliner as a maritime reconnaissance aircraft. It was also probable that an imminent future review might show that the Ministry could no longer maintain a total of ten design companies, which raised the question of whether they needed to maintain in existence so many design teams specialising in large military aircraft.

Finally, Cole indicated that the OR could use existing engines since a relatively small production order was expected which would not justify developing an expensive new engine for this aircraft alone. On 24th September 1953 J E Adamson minuted L J Dunnett, (US[Air]), to propose seeking immediate Ministerial approval to proceed with the LAB since the Air Staff attached much importance to it. The LAB was considered to be no more than the next step in bomber development and its airframe should be no more expensive to produce than the V-bombers. Dunnett's reply indicated doubts that the project was within current electronics and aircraft design resources. From inception, it had been recognised that airframe and missile would need to be very closely integrated within the overall design because the normal bomb bay stowage system did not apply.

On 28th October an invitation for new tenders was close but the situation remained confused as discussions continued. OR.324 (dated 30th October 1953) had now superseded OR.314 with the whole flight to and from the target to be made at an average height of 1,000ft (304m) or less; unrefuelled range was now 5,000nm (9,266km). The aircraft would carry one of three types of special OR.1125 winged, powered and inertia-controlled bombs per sortie, similar in size and weight to Blue Danube, or several smaller stores (a redesign of Blue Danube was proposed). The alternatives were:

- A large subsonic 14,000lb (6,350kg) bomb, 45ft (13.7m) long, 62in (157cm) in diameter.
- A small supersonic 11,000lb (4,990kg) bomb, 35ft (10.7m) long, 33in (84cm) in diameter.
- A small subsonic 7,500lb (3,402kg) stand-off bomb, 35ft (10.7m) long, 33in (84cm) diameter.

A meeting was held at St Giles Court on 11th February 1954 to decide how the LAB should be handled, the project now being viewed as a complete weapon system, but a decision to proceed was never to be made.

By September thoughts had turned towards discontinuing the LAB in the list of requirements and on the 17th, OR.324 was cancelled together with the OR.1125 weapon. The full background was described by the Controller Aircraft, John W Baker, to the Minister of Defence on 4th October. As assessment of the design studies and draft OR by the MoS and Air Ministry proceeded, the difficulties for such an aircraft became alarmingly apparent. The high speeds required at low altitude raised serious structural problems, the bomb would be very complex and expensive, new navigational techniques and equipment would be required, the integration of the total design effort presented great problems of organisation, and if any one of the systems necessary for the carriage and dropping of the bomb should prove unsuccessful, the whole aircraft would be useless.

Such was the magnitude of these problems that the total cost of development was estimated at £12m to £15m. With the danger that the required technical effort and resources could only be concentrated at the expense of other, more important projects, and the huge sums of money involved had to be found within a limited Defence Budget again at the expense of other projects, the Air Ministry decided to cancel its requirement for a low-altitude bomber and the item was deleted from the research and development programme.

In truth B.126 was an information-gathering exercise to bring together the many new aspects and problems associated with high-speed low-altitude flight. For example, the Institute of Aviation Medicine examined air-sickness and the methods needed to counter it since fast flight in rough air at that time simply made the crew ill. Also much greater stresses were exerted on the airframe by rough, bumpy airflows and these had to be accommodated with care, a problem best illustrated by their effect on the Valiant when switched from high to low-level flight in 1963 (see Chapter Three). Within a year, cracks were found in both front and rear spars of many Valiants because the fatigue resistance of these vital parts, designed for high-level flight only, was far short of that needed for prolonged low-level work.

This low-altitude requirement explored much new ground, but it had several weaknesses. For example, meeting the range needed carriage of a phenomenal amount of fuel (all four design studies were essentially flying fuel tanks) and accurate navigation and terrain clearance for these aircraft would have been tough because the relevant equipment had still to be created. The absence of such technology raises an interesting point – jet engine development had made such tremendous strides that it enabled these aircraft to fly close to the speed of sound at low level, yet the design studies still included visual observation with synchronised moving maps. In the event, B.126T only created large volumes of paper, but the knowledge gained helped pave the way for the Buccaneer, TSR.2, Jaguar and Tornado.

Low-Level Bomber Projects to B.126T – Estimated Data

Project	*Span ft in (m)*	*Length ft in (m)*	*Wing Area ft^2 (m^2)*	*t/c %*	*All-Up-Weight lb (kg)*	*Powerplant Thrust lb (kN)*	*Max Speed / Height mph (km/h) / ft (m)*	*Weapon Load lb (kg)*
Avro 721	47 0 (14.3)	80 0 (24.4)	600 (55.7)	11 root 6 tip	124,400 (56,427) (maximum range)	4 x Napier NP.172 5,440 (24.2) + 2 rockets 10,000 (44.4)	Mach 0.94 at 15,000 (4,572)	2 x 5,000 (2,268), one internal, one external, or 4 x 1,000 (454) internal
Bristol Type 186	58 6 (17.8)	92 0 (28.0)	720 (66.9)	9	180,000 (81,647)	2 x Olympus 101 11,000 (48.9) + 4 rockets 3,675 (16.3)	Mach 0.9+ at height	1 x 10,000 (4,536)
Handley Page HP.99	70 6 (21.5)	104 6 (31.9)	1,100 (102.2)	10 root 7 tip	260,000 (117,934)	4 x Avon RA.14 9,500 (42.3) + optional rockets	Mach 0.92 at sea level, Mach 0.92+ at height	1 x 10,000 (4,536)
Short P.D.9	63 6 (19.4)	96 6 (29 4)	1,000 (92 9)	7	195,000 (88,450)	4 x Sapphire Sa.7 11,000 (48 9) + 2 rockets 10,000 (44.4)	Mach 0 96 at sea level, Mach 0 96+ at height	1 x 10,000 (4,536)

Fleet Air Arm Pirate

Buccaneer S Mk.2 XN976 displays Bullpup missiles and rocket pods.

Naval Strike Aircraft: 1954 to 1958

The need for combat aircraft to fly at low level to satisfactorily accomplish penetration of defended airspace without losing most or all of the force was recognised and acknowledged by the Admiralty ahead of the RAF. While the latter conceived and then rejected the Low-Altitude Bomber (see Chapter Four), the Admiralty got to grips turning its thoughts on the subject into its own requirement, although the task must have been made a little easier by the fact that the sea is usually flat. Hills, mountains and electric pylons don't make a habit of turning up in the middle of an ocean.

M.148T (and NR/A.39)

Dated 27th March 1954, M.148T defined a two-seat naval strike aircraft well in advance of current types. Naval Requirement NR/A.39 (or NA.39) had been drafted the previous October, stimulated by the Soviet Union's new and impressive Sverdlov class cruisers, and the aircraft's primary targets were both shore installations and warships. A mix of weapons would be carried but with all-up-weight and size kept within the limits set by its carrier. These comprised one target marker tactical nuclear bomb (TMB) of about 2,500lb (1,134kg), one Green Cheese anti-ship homing bomb, four Red Angel (Special M) bombs, 24 air-to-surface OR.1099 rockets, up to four mines, two 2,000lb (907kg) armour-piercing (AP) or four 1,000lb (454kg) standard MC bombs, or a four-gun 30mm Aden pack. The avionics would include a monopulse radar, lightweight Doppler and a search radar.

After cruise at altitude, low-level bombing was preferred with a high-speed low-level dash to and from the target from beyond radar range, but the Green Cheese attack against large ships was to be 'blind' at medium altitude using the search radar. The maximum possible sea level speed was required, at least 550 knots (633mph/1,019km/h) but more if possible, and a minimum radius of action of 400nm (741km) at low level and 800nm (1,483km) for high attack and search. Flight refuelling was required together with a pack installation to make the aircraft suitable for tanker duties. Folded dimensions were to be 51ft (15.5m) long, 20ft (6.1m) wide. The plane would have two engines and be in service by 1960.

At the end of March, Armstrong Whitworth, Blackburn, Fairey, Shorts and Westland were invited to tender for ten or twenty development aircraft; there would be no prototypes. In addition Percival Aircraft expressed much interest and asked permission to tender which was granted on 13th April. However, after studying M.148T at greater length, Percival visited the MoS in mid-June to explain that it felt unable to produce a complete design for such a complex aircraft, with all the necessary engineering detail, in the available time. The meeting agreed Percival should investigate a 'novel scheme' around a 'ghost' aircraft to meet M.148T which would show a method of generating and deploying engine compressor air to aerodynamic advantage; this was a development of an idea already proposed in a Percival helicopter design. The 'ghost' airframe would be schemed to suit the specification requirements but not developed from an engineering point of view.

In September 1954 the five companies plus Hawker Aircraft tendered their designs. Hawker did not make an official tender with a full breakdown of costs and delivery dates but instead, at a late stage and as an afterthought, sent in a project brochure and drawings. Sydney Camm had shown little interest in the requirement because it called for a bomber, essentially outside the company's favoured area of fighter design, and he only went ahead after the Admiralty made a personal approach. In addition there was no Rolls-Royce engine on hand of an appropriate size to power a twin-engined aeroplane such as this. This lack of interest by Hawker was to be reflected in the design's poor showing against the competition.

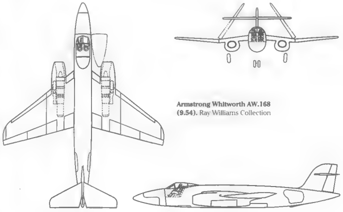
Armstrong Whitworth AW.168

AWA felt the most difficult part of M.148T was to limit normal take-off weight to 40,000lb (18,144kg) since experience showed this increased quickly once the project became hardware. So weight saving became a fundamental part of the study and keeping down the span was important because it reduced structure weight and avoided a second wing fold, with the associated mechanisms that generated. The process proved effective since it allowed enough additional fuel within the 40,000lb limit to increase low-level operational radius with the heaviest store by more than 25% to 510nm (945km).

Alternative layouts had been considered, all of which suffered from a very large central mass. One had two engines immediately adjacent to the fuselage as per the Gloster Javelin and Avro CF-100 which was attractive in regard to single-engine performance and full effectiveness of sweepback. But the need for a large bomb bay relative to the aircraft's size prevented the engines being 'tucked in' to the fuselage unless they were mounted above bomb bay level; then they encroached on the internal fuel. Hence, this arrangement was discarded though its high-speed drag characteristics were very good. Another had underslung nacelles mounted on the inner wing with the main undercarriage placed just inboard, but the retraction method pushed the nacelles too far out along the wing leading to unsatisfactory single-engine characteristics at low speeds. The weight was also prohibitive.

AWA felt big advantages would come from a system bleeding off compressor air and ejecting it at high speed over the flap upper surfaces to prevent airflow breakaway. These included a reduced landing speed or increased landing weight, reduced wing area, a decrease in the deck incidence required to prevent 'sink' on leaving the catapult, and a steeper angle of climb when required. Blown flaps were particularly advantageous for landing and entirely justified on a naval aircraft, but gave nothing to take-off performance. Hence, a deflected jet was also fitted to further augment lift, AWA believing that this, in conjunction with blown flaps, would give all the lift required with minimum extra weight.

Jet deflection would make an aircraft behave as if it had a lower weight than was really the case and was usually effected by pointing the jet pipe downwards to increase lift. On the AW.168, jet deflection consisted of a simple cowl lowered from above the jet-stream to produce a downward local jet angle of 45°. The wing had full-span drooped leading edges working in conjunction with the plain blown flaps. AWA felt that blowing should be used only briefly to boost lift immediately after the catapult launch, then the need was for maximum thrust because a twin-engine aircraft usually attained a measure of safety from rapid acceleration along a near horizontal path – if an engine failed, having the flaps and undercarriage up gave the least possible drag and half thrust would allow flight to continue. In contrast, a single-engine type would achieve safety directly



Armstrong Whitworth AW.168 (9.54). Ray Williams Collection

This page and opposite top: **AW.168 model in Royal Navy livery, a very attractive project that might easily have found itself lining up on the decks of Britain's carriers. The more rearward view shows the array of devices used to increase lift at low speeds.**
Ray Williams Collection

after take-off by a modest increase of altitude at the earliest possible moment while a shore-based aeroplane, instead of accelerating, would initially climb steeply to surmount a 50ft (15m) obstacle; no such limitation existed when flying from a carrier.

AW.168's all-up-weight was 37,000lb (16,783kg) with a Target Marker Bomb, 38,500lb (17,463kg) at maximum weapon load (4,320lb [1,960kg]) and 40,000lb (18,144g) at full load; take-off wing loading was 70lb/ft^2 (342kg/m^2). This was achieved using a simple straightforward layout and structure. The two-spar wing had just the single fold and two de Havilland Gyron Juniors underslung on the inboard fixed portion of the wing with a simple forward-retracting undercarriage contained in the outer nacelle; folded span was 23ft (7.0m). Controls were power operated and all fuel was carried internally, mostly in the fuselage above the bomb bay but also in two inboard wing tanks; a total of 1,690gal (7,683lit) pushed the estimated range to 510nm (945km). Another 500gal (2,273lit) was provided by two plastic underwing tanks while flight refuelling could be incorporated by fitting a nose probe and small additions to the fuel system.

The fuselage had a conventional longeron, skin and stringer assembly. The nose housed the radar and could be folded to cut the AW.168's length by 8.75ft (2.7m) for carrier stowage, while the crew sat side-by-side to further reduce overall length. An all-moving tail was placed high on the fin and the bomb bay had been specially designed to take and deliver the large mix of weaponry. An Aden or Hispano four-gun pack could fit in the bay as alternative armament, in which case bombs were then slung on the outer wing to make up the service load. Considerable drag testing was undertaken in AWA's wind tunnel facilities and a full mock-up was assembled complete with folded wing and nose. AWA proposed that the first two aircraft would be 'flying shells' with a fixed wing and nose and no bomb bay, pressure cabin or jet deflection. The next would have deflected jets, the fourth and all subsequent aircraft would be fully equipped to operational standard. First delivery would be 30 months from date of contract with the twentieth and last aircraft following 14 months later.

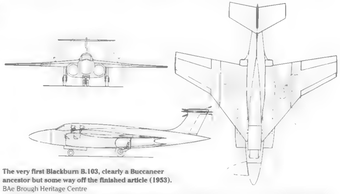
Blackburn B.103

The first B.103 had a 'big' wing, large air intakes and no area rule, Blackburn having rejected a machine powered by a single Avon. Many changes were made before the company completed its brochure and area rule was added at a late stage to give a high

maximum level speed. Blackburn's objective had been to find the best solution to the requirement as a whole rather than place emphasis on any particular aspect. With new developments such as blown flaps reaching a level of practical application, Blackburn felt it had an aircraft of exceptional flexibility of weapon load and range combined with a performance well beyond that requested in M.148T.

The B.103 could take either of two new engines although performance figures were based on a scaled-down de Havilland Gyron Junior called the PS.43 of lower thrust (at 7,000lb [31.1kN]) than the original PS.37's 8,000lb (35.6kN); besides being the first available, PS.43 also showed a 6% improvement in fuel consumption. Supersonic performance was anticipated from more powerful Gyron Juniors or by using the alternative engine, a new 11,400lb (50.7kN) Bristol unit of very similar dimensions and called the BE.33. All-up-weight was well inside the 40,000lb (18,144kg) limit with a substantial margin for development. The engines were placed adjacent to the body; engines further out along the wing were rejected through increased transonic drag and poor asymmetry. Placing them through the wing reduced frontal area and drag and gave the best air flow around wing, nacelles and body.

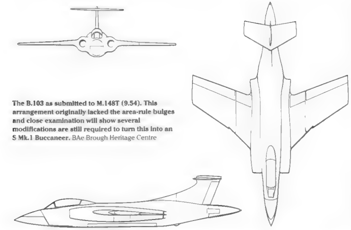
The B.103's structure represented something of a new departure for Blackburn. To give structural strength, two huge machined steel spars were used in the inner wing plus integrally stiffened machined skins on both the highly loaded thin wings and all-moving tail surfaces; a notch was cut in the wing but did not survive into hardware. Fuselage structure was conventional and the engines were mounted adjacent to the fuselage with the main undercarriage retracting sideways into spaces below them. A folding nose housed the radar and a novel rotating and lowering bomb bay door was proposed; in fact the homing bomb was soon cancelled allowing the rotating door to be simplified.



The very first Blackburn B.103, clearly a Buccaneer ancestor but some way off the finished article (1953).
BAe Brough Heritage Centre

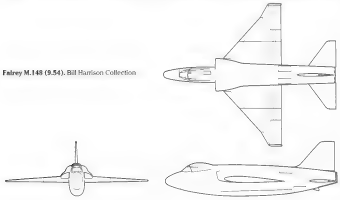
All the specified weapon loads were carried internally but extra weapons could be carried under the wings inboard of the fold. Fuel was housed in the upper fuselage but there was provision for underwing drop tanks and bomb bay fixed tanks. When the B.103 carried Aden guns in the front half of the bomb bay, more fuel could be loaded in the rear. At overload, weapons and fuel could be interchanged and the range extended to twice the specified limit to give tremendous flexibility (a 1,115nm [2,066km] radius of action). This could be further extended to 1,300nm (2,409km) by completely filling the bomb bay with fuel which was to be the arrangement when the aircraft flew as a flight refuelling tanker. Service ceiling was 35,000ft (10,668m).

High-speed air from the engine compressors was blown over the flaps and ailerons, the outer wing upper surface from just aft of the leading edge, and the tailplane, to give remarkable low-speed characteristics. This arrangement increased available lift, gave good stalling characteristics and full lateral control down to the stall. The air was bled from the engine compressor and test results showed the project would satisfy all carrier operation take-off and landing demands. In fact the team at Blackburn, under the leadership of Barry Laight and Roy Boot, had examined bleeding of hot high-pressure air in much more depth than anyone else and the results transformed the aircraft and set new standards. Blackburn considered the B.103 offered the prospect of a clear lead over contemporary aircraft, provided it was brought into service at the earliest possible time; it was in no way inferior to a land-based aircraft designed for similar duties.



The B.103 as submitted to M.148T (9.54). This arrangement originally lacked the area-rule bulges and close examination will show several modifications are still required to turn this into an S Mk.1 Buccaneer. BAe Brough Heritage Centre

Model of the B.103 to M.148T.
BAe Brough Heritage Centre



Fairey M.148 (9.54). Bill Harrison Collection

It was intended to have the first aeroplane flying 33 months from date of contract with the tenth and last development aircraft ready just under two years later. If 20 machines were ordered, the programme would be accelerated. The first two or three airframes would be 'flying shells' without folding wings or nose, radar and navigation equipment, bomb bay doors, pressure cabin and weapons. Blackburn's Drawing Office was at the end of large-scale work for the Beverley transport and its staff could be rapidly transferred to the B.103 for a 'flying start' to the programme.

Blackburn envisaged using a BE.33 powered B.103 as a carrier-borne all-weather fighter which offered a much improved performance and extended the scope for different roles. It would also be more adaptable for supplying air for boundary layer control but no engines would be available for the B.103 prototypes. For an increase in weight of about 1,500lb (680kg), a BE.33/B.103 could achieve a level Mach 1.05, cruise at 45,000ft (13,716m), have a greater rate of climb (22,500ft/min [6,858m/min] at sea level and 40,000lb [18,144kg] weight) and 15% more range. The company also briefly considered a third engine, the Armstrong Siddeley P.151.N, which was broadly similar to the Gyron Junior but its future was uncertain. Gyron Junior was expected eventually to give 10,000lb (44.4kN) unreheated thrust and a maximum Mach 1.03. As built the S Mk.1 Buccaneer lacked power and would have benefited from the BE.33's additional thrust; this problem was not addressed until the S Mk.2 arrived with Rolls-Royce Speys.

Fairey M.148

Fairey felt it would be difficult to meet most or all of M.148's requirements and numerous and extensive studies were made of various configurations before the design to be submitted, which represented the best compromise, was selected. It incorporated some advanced aerodynamics and structure and would be easily maintained. Because of the large fuel load, a big problem had been to keep within the size limits, but the delta wing did allow a reduced t/c ratio to give the same structure weight as a conventional swept wing plus a better high-speed performance. The result had a multi-spar wing, deep fuselage and low-set all-flying tailplane, design experience with the Delta II supersonic aircraft supplying the background information for the wing choice. There was a single wing fold and the main undercarriage, positioned just inside the fold, retracted sideways into the wing centre section. All controls were power operated.

Single, twin and multi-engine installations were investigated before Fairey chose two Gyron Juniors mounted side-by-side on top of the wing centre section. Originally, Fairey had been biased against de Havilland's engine and had pushed the Ministry to 'urge Rolls-Royce to make a lightweight Avon'. Sea level rate of climb was 5,010ft/min (1,527m/min) at take-off weight and the climb at altitude was expected to be ample for the high-level dropping of Green Cheese. The dive bombing requirements were met using the dive brakes which could hold the aircraft at 576mph (927km/h) EAS in a 60° dive from 20,000ft (6,096m), at a weight of 35,000lb (15,876kg). Top speed at 30,000ft (9,144m) was 578mph (930km/h).

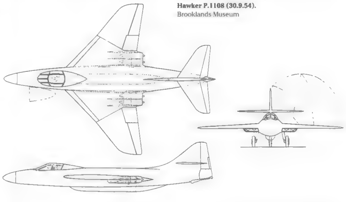
The fuselage used conventional light alloy semi-monocoque construction throughout. Its bomb bay was situated under the wing centre section, the doors retracting into the bay with front and rear fairings provided to assist airflow. Fairey explained that some lowering gear would be required for the Green Cheese and 'push off' equipment for the Target Marker Bomb. For additional lift at low speeds, the machine had leading-edge slats and double-slotted flaps with supersonic blowing over the flaps (a system described by a Ministry assessor as half-hearted – 'the firm supplied no details for the blowing system which had clearly not been thought out'). At normal landing weights and with flaps extended (but without blowing), the approach speed for carrier landings was estimated to be 140mph (225km/h); with blowing the approach speed was 129mph (208km/h). Fuselage and wing tanks gave a range of 1,660 miles (2,672km) which could be increased to 2,130 miles (3,428km) by fitting two 300gal (1,364lit) overload tanks for an all-up-weight of nearly 45,000lb (20,412kg).

Fairey estimated it would need three years to deliver the first aircraft and 69 months to complete the twentieth, but the brochure lacked specific build details and the assessor could only assume that the first would be built to a full naval standard but initially unequipped. The brochure offered as an alternative one RA.24 Avon with span increased to 45ft (13.7m) and wing area to 550ft² (51.2m²), but sea level speed fell to 645mph (1,038km/h) and rate of climb to 3,855ft/min (1,175m/min). Except for the engine installation, this aircraft was essentially the same and had an all-up-weight of 38,500lb (17,464kg).

Hawker P.1108

As noted, Hawker had shown little interest in M.148T and this project was put together at the last minute. Nevertheless, it still displayed some typical Kingston curvature, particularly in the wing. As Rolls-Royce had no suitable engine for a twin-powerplant configuration (Hawker favoured the Derby company), the choice settled on a unit still on the drawing board, the small 20in (51cm) diameter RB.115. Four were placed in pairs under the inner wing. The single wing fold began just outboard of the engines but was then angled outwards to make room for a leading-edge slat on the inner wing; a fixed tail with movable elevators was located near the bottom of the fin. P.1108 had a tricycle undercarriage with the main gear folding rearwards into the side fuselage; two crew were seated side-by-side while the nose, with the radar, could be folded to reduce length by 7ft (2.4m). The bomb bay was designed to partially enclose the Green Cheese nuclear weapon for semi-buried carriage. Since this was not an official tender, there were no estimated delivery dates.

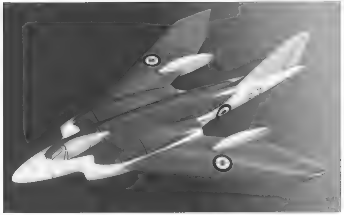
Model of the dumpy Fairey M.148.

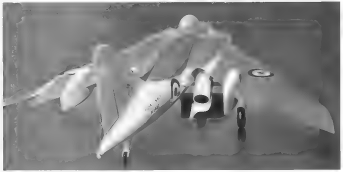


Hawker P.1108 (30.9.54).
Brooklands Museum

Short P.D.13

Shorts noted that M.148T could be met with a conservative design of top speed 630mph to 690mph (1,014km/h to 1,110km/h) but felt that a much better performance was desirable. If a naval strike aircraft was to have a long life on first-line duty, it should not fear an encounter with anything but the first-line fighters of the major air powers. Hence a target of Mach 1 in level flight was set coupled with a very high degree of manoeuvrability. However, the low wing loading normally required by deck-landing aircraft was not conducive to attaining transonic speeds so Shorts' solution was to use high power to augment lift at low speed, a move which also substantially reduced wing area, structure weight and drag. The method chosen was to deflect the jet pipe itself to give a measure of direct lift and it was found that the saving in fuel and structure weight was sufficient to offset the weight of the more powerful engines. Hence the design offered high performance





and no weight penalty over the conventional lower performance alternative (Shorts had examined a delta with two 10,500lb [46.7kN] Avon 27s).

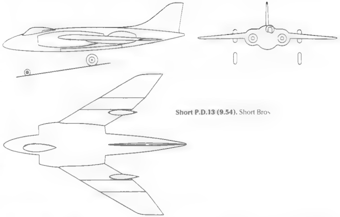
A highly swept 'V' wing similar to that of the experimental Short S.B.5 was chosen so that the jet efflux at the root of the wing trailing edge could be deflected downwards without producing a change of trim. With such a large angle of sweepback there was no need for a tailplane, the control, stability and damping in pitch being satisfactory throughout the speed range. Moreover, a low tail could not be used with jet deflection and a high tail had been shown to be unsatisfactory, especially at the stall. The P.D.13 was therefore tailless and featured Geoffrey Hill's 'aero-isoclinic' wing with tip controllers. For control at high speeds on a tailless aeroplane, all-moving wing tips, equivalent to the all-moving tail on conventional high-speed aircraft, were considered essential. On this aircraft the usable rate of roll would be determined by the pilot's ability to withstand acceleration, not by the limits of aileron effectiveness; hence, at Mach 0.85 at 5,000ft (1,524m) the theoretical maximum rate of roll was around 800°/sec. At low speed the controls had to be particularly effective and here again the all-moving tips were eminently suitable.

The resulting configuration was not unlike Shorts' S.B.4 Sherpa experimental aircraft and the excellent handling qualities of that aeroplane had given the company the confidence to produce this design, which it was felt could be undertaken without any further development programme to prove the control system. P.D.13's performance figures substantially exceeded those demanded by M.148T and it was capable on emergency power of supersonic speeds at height. Best sea level rate of climb was 24,000ft/min (7,315m/min) although a take-off at 39,600lb (17,963kg) cut this to 11,800ft/min (3,597m/min); operational ceiling was 34,800ft (10,607m).

The two-spar wing had a single fold. Inside this the main wheels folded rearwards into their own trailing-edge nacelles whilst the nosewheel could be extended by the pilot on the deck to put the aeroplane into catapult attitude. Wing construction was semi-orthodox in that, owing to the breaks at the controller and fold, most bending and torsion would be taken by the spars. Integral fuel tanks were placed in the inner wing forward of the spar with the rest of the fuel carried above the bomb bay; there was no in-flight refuelling. The fuselage used standard frame and stringer construction with a rotating bomb bay door and a lowering bomb bay floor. The cockpit had tandem seating (to reduce drag) and an ASV.21 search radar was carried in the non-folding nose. Two Avon RA.19s with full jet deflection were mounted close to the fuselage. All-up-weight with the TMB was 40,000lb (18,144kg), rising to 40,520lb (18,380kg) with Green Cheese. First delivery would be in 30 months with the twentieth in just under five years.

Top **Impression of the P.1108 showing the small powerplants and semi-buried Green Cheese.** BAE Systems

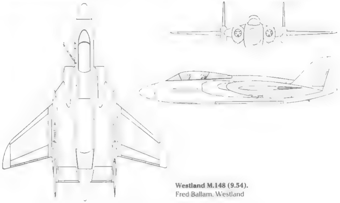
Centre left and bottom: **Model of the Short P.D.13. Note the raised pilot's and enclosed navigator's cockpits, the jet deflection, main undercarriage wing nacelles, and the 'isoclinic' wing tip controllers.** Short Bros



Short P.D.13 (9.54). Short Bros

Westland M.148

One aircraft to be replaced by M.148T was the Westland Wyvern and its manufacturer offered a successor. This project was unusual in having twin fins and rudders with the space between them and the fuselage filled by the elevators. Two Gyron Juniors were placed either side of the fuselage and the jet pipes could be rotated for jet deflection (BE.33s were an alternative offering greater take-off and landing thrust). The aircraft also had a tricycle undercarriage and a small tailwheel so that it could squat on its tail for a catapult take-off at a wing 'angle of attack' of 15°, the nosewheel being lifted above the deck. The two-spar wing folded just outboard of a fence that housed the retracted main undercarriage, the fence continuing backwards to form a 'boom' for a fin and rudder. Fuselage construction was conventional and because the project was short and stocky, there was no need for the nose to fold. The weapons were all carried internally on a bomb beam retracted into the roof of the bay for carriage and lowered to the open doors for delivery. All the fuel was housed in upper fuselage tanks above the bomb bay and a folding flight refuelling probe was placed to the port side of the cockpit. Design dive speed was 760mph (1,223km/h). Westland's timetable from ITP estimated 125 man-weeks to complete design and 105 weeks to first flight, leaving out some equipment.



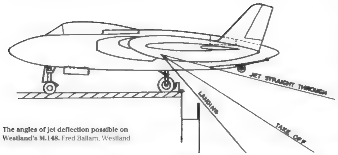
Westland M.148 (9.54). Fred Ballam, Westland

Saunders-Roe P.178

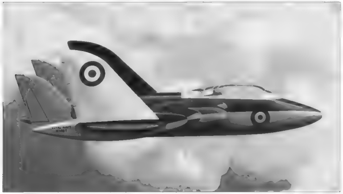
In the period up to the issue of M.148T, Saro completed two naval strike aircraft designs that seem to fit closely to the requirement, but the drawings mention no specification and no brochures were submitted. They do, however, show a TMB in an internal bay. Both had side-by-side seats, twin Gyron Junior PS.37 engines, an all-up-weight of 40,000lb (18,144kg) and a 4,000lb (1,814kg) bomb load. P.178/1 had engines in pods above the rear fuselage; span was 37ft 6in (11.4m), length 48ft 9in (14.9m), wing area 470ft² (43.7m²), thickness/chord ratio 8% and wing loading 85lb/ft² (415kg/m²). P.178/2 had PS.37s in pods above the wings; span 39ft 0in (11.9m), length 51ft 0in (15.5m), wing area 520ft² (48.4m²), t/c 8% and wing loading 77lb/ft² (376kg/m²).

Before the Design Conference, the suitability and workloads of the companies and their varying design experience were assessed. AWA was currently engaged on Sea Hawk development and production and, apart from the AW.52 high-speed tailless aircraft and Apollo airliner, had a design staff that in recent years had worked solely on aircraft designed by other Hawker Siddeley companies (Meteor NF Mk.11 and Sea Hawk). Its most recent tender however, the Mach 2.5 AW.166 research aircraft to ER.134T, had been a very close second to the Bristol 188. The team was young and of good quality, borne out to some extent by the detailed M.148 brochure.

Blackburn's work on the Beverley freighter was expected to diminish by the end of the year. The company had a naval background through its Firebrand and GR.17/45 aircraft and in recent years had strengthened its top



The angles of jet deflection possible on Westland's M.148. Fred Ballam, Westland



Centre left and bottom left: **Westland M.148 model complete with twin fins. The underside view shows the rotating jet pipes and small tailwheel.** Both Fred Ballam, Westland

design staff. But its only recent high-performance design was the HP.88 crescent wing research aircraft sub-contracted from Handley-Page, though its B.89 naval fighter to N.114T had tied with Westland on technical merit. B.103 would be more difficult to design and build than the AW.168, chiefly through the introduction of machined skins and large complex centre section forgings.

Fairey was fully occupied on Gannet modifications and development, Rotodyne and ultra-light helicopter design, and flight development of the Delta II research aircraft, so its design capacity would be fully employed until mid-1956. Recruiting enough additional staff was impossible and Fairey's proposal to subcontract the M.148 or existing work was not considered feasible. It was felt that in spite of the company's acknowledged experience in naval and high-performance aircraft, if Gannet development was to proceed unhindered, M.148 should not go to Fairey on the grounds of a complete lack of design capacity. Shorts were only engaged on the Seamew and the experimental vertical take-off S.C.1 projects and had ample staff available for M.148. The company had a naval design background (Sturgeon and Seamew) and recent low-speed swept-wing experience (S.B.5 and Sherpa), while its design administration was excellent and considered to be without equal in the industry. The lack of a tail on the P.D.13 made for a simpler design and construction task, but the time saved might be lost by the extra flight testing required to develop the controller and jet deflection.

Hawker and Westland were not assessed in detail. Hawker was considered short of manpower because of its Hunter work – basically a single-seat fighter company but with naval and high-performance experience, it was yet to tackle a project of this size. It was also understood that availability of the proposed RB.115 would not match the official MoS programme for M.148. Westland was a relatively small company which had designed the jet deflection Meteor and had recent naval experience with the Wyvern; current work included Wyvern modifications and Whirlwind helicopter development. But the company was very short of design capacity and needed either to recruit at least 100 extra staff or sub-contract about 60% of M.148 detail design; its brochure admitted this deficiency. Westland's programme proposals were regarded as well conceived but the

quoted flight dates were felt to be optimistic by some nine months, particularly in view of the design staff situation. J R Webber (of RD Projects Department) completed this assessment on 18th November 1954.

The Tender Design Conference took place at the home of the MoS, St Giles Court, on 3rd December 1954. At the outset both Hawker and Westland were rejected, the former by reason of no formal tender submitted, the latter because its proposal had little merit with a performance appreciably less than required; Westland was also considered to have insufficient capacity. All the survivors had a comparable performance in the dive but Shorts just failed the high-altitude cruise limits and Fairey missed them by some margin. AWA, Blackburn and Fairey all proposed a degree of sonic blowing but did not depend on this to meet the performance requirements, but the Shorts project totally depended on its jet deflection to meet them. AWA and Shorts were somewhat on the heavy side.

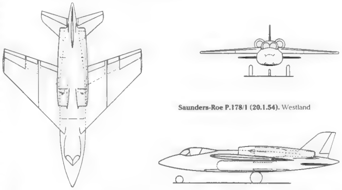
Blackburn's was a progressive design on which the company had done much tunnel work; the project held great promise and the sonic blow scheme seemed satisfactory, but more tunnel testing was desirable for handling purposes. With its jet deflection and wing tip controllers, Shorts' was also very advanced but more doubtful in achieving performance due to the many unknowns associated with the design. The configuration was logical for a Mach 1.4 aircraft but the gain for a Mach 1.0 type was not so obvious making the uncertainties of the tip controller unjustified. Shorts' jet deflection proposals were also regarded with some doubt. Everyone had been attracted by this novel design, but no tailless aircraft had so far proved satisfactory in service and it seemed unwise to choose the configuration for the most difficult case of all in deck landing. Moving to the various companies' different ways to increase lift, it was agreed that, despite a lack of experience, the use of blowing showed great promise.

Operationally, the chosen aircraft would be in service beyond the mid-1960s and would need adequate development potential. Blackburn's project was considered the best from all operational considerations such as equipment installation and ease of maintenance. It was felt that the company had made a welcome advance with its integral construction technique and there was every reason to suppose it would prove satisfactory, but the need for new machine tools would extend the development time. RAE preferred the simpler AWA proposal, but there were doubts about its weight estimates. The AW.168 was the only aircraft likely to meet the 1960 in-service date and AWA's high quality of production made it a clear first choice here. Neither Shorts nor Blackburn could be relied upon to meet the date and Fairey was definitely out due to lack of design capacity. Blackburn had little past experience on high-speed aircraft and its current manufacturing reputation was poor but the Naval Staff said it would prefer the B.103 in 1961 rather than the AW.168 in 1960. Fairey's tender was the least satisfactory and was not considered further.

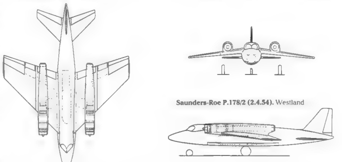
The order of merit was:

1. Blackburn. B.103 appeared to offer the Naval Staff what it required and should have reasonable development potential and remain useful well beyond its date of entry into service (nobody could have predicted this would mean the 1990s). It offered slightly more risk than AWA's and seemed to represent the best compromise between the technical quality likely to be obtained and the certainty of obtaining it.
2. Armstrong Whitworth. A more conventional design which could be relied upon to enter service by 1960 but with a relatively short useful life. It was heavier than the other two and offered the most predictable and certain development but, technically, the smallest advance; there was little promise of further development.
3. Short Bros. and Harland. A greater gamble than choosing Blackburn through uncertainties over the wing tip controllers. The degree of risk was very high.

Ordering two types, the B.103 and AW.169, was considered with one to be halted after a year when wind tunnel and initial design work would show which was the superior. But it was agreed that it might still be difficult to choose between them so, on the 9th December 1954, recommendations were made that the B.103 should be the only aircraft ordered to M.148. The B.103 was christened Buccaneer and the first aircraft took to the air on 30th



Saunders-Roe P.178/1 (20.1.54). Westland



Saunders-Roe P.178/2 (2.4.54). Westland

April 1958. Forty S Mk.1 Buccaneers were built with Gyron Junior turbojets but a lack of sufficient thrust, particularly in hot conditions, made them operationally inadequate. The first S Mk.2 with more powerful Rolls-Royce RB.168 Spey turbofans, a military version of the RB.163 civil engine, flew on 17th May 1963 and showed great improvement.

The Buccaneer was rejected several times by the RAF, often in vitriolic fashion, but eventually politics, cancellations and circumstance combined to give the RAF no choice but to take it as the S Mk.2B. Later chapters will show how the RAF lost its TSR.2, F-111K and AFVG which presented a potentially catastrophic situation when one considers the capability of the Soviets. However, the Buccaneer was so ahead of its time that it comfortably filled the gap. Had the AW.168 been built it most likely would have served the FAA well through the 1960s but it would not have been suitable to fill the RAF's tactical strike and reconnaissance requirements for the 1970s.

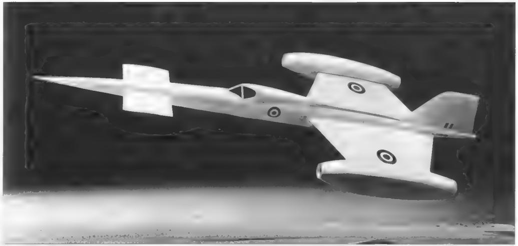
H R 'Hal' Watson, Chief Designer at AWA, was particularly disappointed at losing out having reached the 'semi-finals'. In fact AWA produced a string of good designs between the late 1940s to mid-1950s, all of which just missed being turned into a prototype. The AW.56 is described in Chapter Two while *British Secret Projects: Fighters* describes how AWA's projects were pushed out by the Lightning, Bristol 188 and Fairey 'Delta III'. This was bad luck and reminds one of Lavochkin in Russia who built a line of jet fighter prototypes through the same period, all of which lost out to products from other manufacturers. At least Lavochkin did build his prototypes.

The Navy's new large carrier programme was abandoned in 1966 and a run-down in naval fixed-wing capability began with some FAA Buccaneers passing to RAF hands. After cancellation of the F-111K in January 1968, an additional new-build order was placed to ASR.391 and the type served faithfully and successfully with the RAF until 1994. Early Buccaneer weapons included the American Bullpup air-to-surface missile (ASM) and Anglo-French Martel, a TV-guided ASM developed in the 1960s; both of these missiles were rocket powered. The longer-range British Aerospace Sea Eagle, developed from Martel, was a jet-powered ASM produced from the late 1970s to ASR.1226 as an over-the-horizon fire-and-forget weapon; it remains in service today, using an active radar and has a sea-skimming capability.

Naval Strike Aircraft Projects to M.148T – Estimated Data

Project	*Span* ft in (m)	*Length* ft in (m)	*Wing Area* ft^2 (m^2)	*t/c* %	*All-Up-Weight* lb (kg)	*Powerplant* Thrust lb (kN)	*Max Speed Height* mph (km/h) ft (m)	*Weapon Load* lb (kg)
Armstrong Whitworth AW.168	47 6 (14.5)	59 9 (18.2)	555 (51.6)	8.5	40,000 (18,144)	2 x DH PS.43 Gyron Junior 7,000 (31.1)	674 (1,084) at sea level	Green Cheese (GC), TMB, Red Angel (RA), bombs, air-to-surface rockets in bomb bay or under wings
Blackburn B.103	42 6 (13.0)	61 6 (18.8)	535 (49 7)	9 to 6	39,308 (17,830), max. overload 46,000 (20,866)	2 x PS.43 Gyron Junior 7,000 (31.1)	737 (1,186) at sea level, Mach 0 97 to 0 98 at all heights up to 30,000 (9,144)	GC, TMB, 4 x RA, 4,000lb (1,814kg) of bombs or 24 RPs in bomb bay; 2 x GC, 4 x RA, 4,000lb of bombs or 24 RPs under wings
Fairey M.148	42 0 (12.8)	51 0 (15.5)	500 (46.5)	9 inner wing, 5.3 tip	39,500 (17,917)	2 x PS.43 Gyron Junior 7,000 (31.1)	658 (1,059) at sea level	Mix of Green Cheese, TMB, Red Angel, 4,000lb (1,814kg) of bombs, RPs in bomb bay or under wings
Hawker P.1108	40 0 (12 2)	58 0 (17 7)	510 (47 4)	7	?	4 x RR RB.115	?	Mix of Green Cheese, TMB, Red Angel, bombs, RPs in bomb bay or under wings
Short P.D.13	38 1 (11.6)	51 0 (15.5)	482 (44.8)	10 root 7 tip	40,520 (18,380)	2 x Avon RA.19 12,500 (55.6)	758 (1,220) at sea level, 709 (1,141) at 30,000 (9,144)	Mix of Green Cheese, TMB, Red Angel, bombs, RPs in bomb bay or under wings
Westland M.148	43 0 (13.1)	50 10 (15 5)	863 (80.3)	not given	40,915 (18,559)	2 x PS 43 Gyron Junior 6,830 (30 4)	674 (1,085) at sea level, 564 (907) at 35,000 (10,668)	1 x GC or TMB, 4 x RA, 8,000lb (3,629) of bombs (overload), mines or 24 RPs in bomb bay
Blackburn Buccaneer S Mk.2 (Flown)	42 4 (12 9)	63 5 (19.3)	508.5 (47.3)	9.25 to 6	51,000 (23,134)	2 x RR Spey 101 11,030 (49 0)	Mach 0.95 or 668 (1,075) IAS clean	Normal 4,000lb (1,814kg) internal: bombs, Sea Eagle, Martel, RPs external

High-Level Finale



Artist's impression of the Avro 731 Flying Scale Model Aircraft.

High-Altitude Reconnaissance Bombers: 1954 to 1957

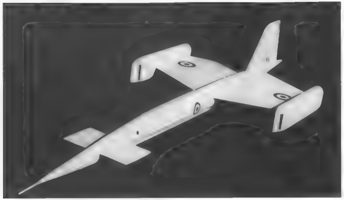
There was one last attempt to get another high-altitude bomber into RAF service. It began with a supersonic reconnaissance requirement that was intended to fill a vital gap in RAF capability against the Soviet Union. Had the winning Avro 730 been completed and flown it would have been a major achievement but, once again, significant advances in the development of defensive Soviet surface-to-air guided weapons quite literally brought everything down to earth and made the 730, at least in British eyes, an outdated and obsolete concept. The Avro 730 had much in common with the American Lockheed SR-71 Blackbird and pre-dated it by a year or two. Early American studies looked similar to some of the designs described in this chapter but America saw its programme through to fruition and the SR-71 served for many years. Whether Britain should have completed its machine, and would it have been worth the cost, is an argument that most likely will never be settled.

R.156T (and OR.330)

The story of Avro 730 began on 23rd July 1954 during Air Ministry discussions for a radar reconnaissance aeroplane. Britain's nuclear strike force was fully catered for by the V-bombers but the problem of providing reconnaissance for these aircraft when using stand-off bombs was very important to the Air Staff. A draft OR was proposed which was formally issued in August, the Air Staff having been advised that any attempt to combine both bombing and reconnaissance in one aeroplane might delay it for two years. A planned replacement bomber was, therefore, put in abeyance and the pure reconnaissance Tender Specification was completed on 27th October. It was the first of a new type written on the basis of the weapon system concept whereby the aircraft and its equipment were treated as a single entity. Tenders were invited in January 1955 and five companies submitted brochures in the summer for what was an incredibly advanced requirement; Britain's first supersonic fighter was still some years from entering service.

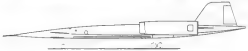
Specification R.156T requested a supersonic high-altitude reconnaissance aircraft to obtain radar and photographic information for conducting offensive operations and it was to be capable of operation by day and night in any weather. This would necessitate deep penetrations of enemy territory and success depended on the ability to maintain the highest possible cruising speed at the greatest possible altitude throughout a mission. Collecting satisfactory radar reconnaissance data was the more important role and performance was not to be compromised by including large and heavy photographic systems. Minimum still air range was 5,000nm (9,265km) and cruise ceiling was to be as high as possible but not less than 60,000ft (18,288m) when 1,000nm (1,853km) from base; normal operational heights would be between 45,000ft and 70,000ft (13,716m and 21,336m). Top speed was to be as high as possible and in excess of Mach 2.5 at maximum cruise altitude.

Speedy development was vital. OR.330 asking for completion as soon as possible and as near to 1960 as practicable. An early pro-

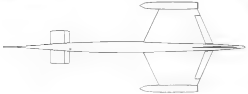


Model of the Avro 730 as originally tendered.

duction date was to be a principal factor in design selection and the Air Staff was prepared to consider slight reductions in performance (Mach 2.0 cruise and 4,000nm [7,412km] range) coupled with a promise of further development if this would substantially advance the service entry date. Because of the high cruise speed, kinetic heating would be severe so the designers were expected to examine this thoroughly and prepare a comprehensive heat balance covering all probable conditions of operation including the capability of all the equipment to withstand such temperatures. Design configuration was left open and the resulting tenders brought forth layouts of great variety and technical interest.



Avro 730 (7.55).

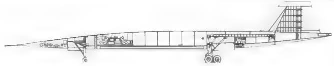


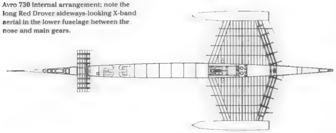
Avro 730

Avro identified a big problem with OR.330 in that for any powerplant currently promised by the engine manufacturers, the requirement was difficult to meet within a weight of about 200,000lb (90,720kg). Consequently, the design had to ensure maximum efficiency, both as regards aerodynamic drag and structure weight. At the required height and Mach number, the 730 was designed to achieve a still air range of 4,500nm to 4,700nm (8,339km to 8,709km). To obtain this some relaxation of present practice had been assumed including indirect vision for the pilot (a periscope would be used for landing though a raised canopy was available for early development flying); flight refuelling was not fitted.

Consideration had been given to a reduced size and development time. At Mach 2.5 the skin temperature would be 190°C, at Mach 2.0 this fell to 100°C thus permitting an aluminium alloy structure for the latter condition. However, Avro based the 730's structure on high tensile steel since this permitted the specified Mach 2.5, arguing that its known and reliable properties offset the shorter development time of light alloy; it also offered possible development to even higher Mach numbers. Construction was to be in brazed honeycomb sandwich, tests to date having indicated that this gave the same advantages over conventional methods as a similar light alloy honeycomb had given the Avro 720 rocket fighter. The manufacture of sandwich panels was a straightforward technique that avoided the need for expensive machine tools to produce integrally stiffened skins.

A further consequence of aiming for Mach 2.5 was the chance to use an unswept rather than highly swept wing. Although a wing leading edge swept behind the Mach lines would exhibit lower drag up to Mach 2.0, Avro's studies clearly indicated that the drag of an unswept wing was less at the Mach numbers required by R.156T. Furthermore, the unswept wing was suitable for development to any Mach number whereas the highly swept-back wing was limited to a Mach number somewhat below that at which its leading edge became supersonic. Other advantages of a straight wing were more lift at take-off and landing and the ability to place the whole of the powerplant at the wing tip, a structurally convenient move since the intakes were unaffected by the airflow around the aircraft and the nacelles acted as end-plates to improve lift at subsonic speeds.





Avro 730 internal arrangement; note the long Red Drover sideways-looking X-band aerial in the lower fuselage between the nose and main gears.

Some felt that the optimum powerplant for supersonic aircraft should consist of a large number of relatively small engines, the plus factors being low specific weight coupled with a shorter development time over a larger unit. But studies by Avro of nacelles housing various numbers of engines revealed that the small unit's lower weight was offset by extra installation weight from the multiplicity of engine mountings, fuel systems and jet pipes. In addition, to obtain a good aerodynamic installation, the intake's leading edge should be ahead of the wing whereas the final nozzle must not be forward of the trailing edge, thus the total nacelle length had a minimum value which was dictated by the wing chord. Fitting two large engines to the 730's wing tip had shown that the minimum length of intake plus engine and propelling nozzle was little more than the wing tip chord; for the same total thrust a nacelle with numerous small engines would have greater weight and drag.

Wing tip nacelles also presented the opportunity to introduce changes of engine and configuration with only minor effects. Comparative studies were continuing for aircraft with four, six, eight and sixteen engines but the brochure offered a design based on four Armstrong Siddeley P.159s with two Armstrong Siddeley rocket motors underslung on the mainplane to assist take-off. Alternatives were four modified de Havilland Gyrons, four Bristol BE.36s, six Rolls-Royce RB.122s without reheat or 16 of the new Rolls-Royce RB.121s; thrust ratings were: RB.121 5,465lb (24.3kN), P.159 20,750lb (92.2kN), PS.48 Gyron 18,510lb (82.3kN), BE.36 17,950lb (79.8kN). At Mach 2.5 the major part of the compression took place in the intake rather than the engine compressor. Therefore, intake efficiency had a considerable effect on overall performance and, in consequence, Avro proposed an intensive development programme to examine this area as a whole.

A supersonic aircraft would normally be designed to be statically stable longitudinally at subsonic speeds. The inevitable aft movement of aerodynamic centre at supersonic speeds led to excessive stability which, in the case of tailless or tail-aft aeroplanes, would give rise to trim drag. Hence, the 730 had been designed as a tail-first aircraft because this gave a big reduction in trim drag. This configuration also developed more lift at take-off and landing, the fuselage fitted very conveniently with the radar to give an aerial unobstructed by the wing and noseplane and the all-moving noseplane could be mounted on the fuselage itself, which saved development time compared to an aft tailplane high on the fin. Canard span was 21ft (6.4m) and gross area 276ft² (25.7m²). (On all OR.330 canard submissions, the canard was not there so much for high lift but to assist take-off rotation due to the very long, slender fuselage.)

Half of the 730's take-off weight was fuel and a wing loading of about 100lb/ft² (488kg/m²) ensured that take-off could be accomplished from normal aerodromes without resorting to special devices, except moderate RATO. The undercarriage had a single main leg positioned slightly aft of the centre of gravity and a conventional nosewheel while the aircraft's lateral position at rest and slow speed was maintained by outriggers below each nacelle. To avoid distorting the fuselage shape four of the eight main undercarriage wheels were jettisoned after leaving the ground. The primary equipment for OR.330 was the Red Drover sideways-looking X-band radar for which two 52ft (15.85m) long aerials were provided in the lower fuselage between the nose and main gears.

Total fuel capacity was 14,320gal (65,112lit) of which 3,200gal (14,550lit) was housed in wing tanks, the rest in the fuselage. At 222,660lb (100,999kg) weight, sea level rate of climb was predicted to be 12,300ft/min (3,749m/min); maximum height was 70,000ft (21,336m) but 93,000ft (28,346m) was possible in a zoom climb. A two-shock intake gave a Mach 2.5 cruise, a height of 60,600ft (18,471m) after flying 1,000nm (1,853km), a maximum height of 72,100ft (21,976m) and a still air range of 4,500nm (8,339km); the equivalent figures for a three-shock intake were Mach 2.6, 62,200ft (18,959m), 73,800ft (22,494m) and 4,740nm (8,783km). One pilot and two navigators were carried but, later, a second pilot was accepted.

A large aircraft built in steel honeycomb sandwich and employing a tail-first arrangement represented big departures from current practice. When the brochure was completed much low-speed wind tunnel testing had been accomplished which showed good results both longitudinally and laterally, but supersonic tunnel work was yet to begin. It was intended that the first aircraft would fly in November 1959, three more would complete in 1960 with service entry in second quarter 1964. The 730 was designed purely as a reconnaissance aircraft but Avro expected a requirement would eventually arise for a bomber of similar performance to carry a ballistic bomb or, later, a powered stand-off bomb. A 730 mock-up was built.

English Electric P.10

This was designed to cruise above 70,000ft (21,336m) at Mach 3.0. Again a canard, it had a ducted ramjet wing boosted by two turbojets in the rear wing root, a remarkable and novel feature. Propulsive power during cruise was supplied by the Napier ramjets burning at low fuel/air ratios with the turbojets acting mainly as auxiliary powerplants. Integration of the ramjet propulsive system with the wing necessitated an intimate relationship between its design as a load-carrying structure and as a system of bypass ramjets.

The wing was an integrated lifting and propulsive unit designed to give low supersonic cruising drag combined with large structural depth. To provide a sufficiently stiff and strong structure without interfering with the propulsive duct a 'Warren Girder continuum' was employed consisting of a multiplicity of spanwise Warren girders with continuous chordwise 'ribs' along its diagonals, which defined the ducts laterally. Upper and lower wing skins and an integral tank in the diffuser completed the duct and a deep spar extended below the front face of the Warren continuum to increase bending and torsional stiffness.

The flat wing panels were amenable to sandwich construction, either in steel or titanium, and the use of tip winglet extensions attached to the web of the spar to form subsonic drop tanks gave no significant weight penalty. These were to provide fuel for take-off, acceleration and climb and, though handed, were of constant subsonic aerofoil section; jettison would occur near Mach 0.9 at 36,000ft (10,973m). In the region that formed the ramjet burner section a mesh insulation provided protection for the wing structure which at no point passed through the gas stream. A simple two-dimensional nozzle was split into segments by vertical plates which served to brace the trailing-edge structure. Tunnel testing would determine if the outer segments of this nozzle flap could pro-

vide sufficient effect as low-speed ailerons and also see if the inner segments could act as landing flaps.

Area rule was applied to the comparatively conventional fuselage that housed the fuel and equipment. Despite high surface temperatures (typically 240°C) on the nose section forward of the foreplane, a lack of loading (coming only from internal pressures) permitted the use of conventional light alloy skin-stringer construction in this region for a superior aerodynamic finish. To combat the heavier fuselage loads experienced between the foreplane and wing, alternative methods of construction comprised steel skin and stringers or double-skin sandwich with differing materials on the outer and inner skins to relieve thermal stresses – both skins would be load carrying. A pear-shaped fuselage section helped to provide the critical level of stiffness required in the vertical plane.

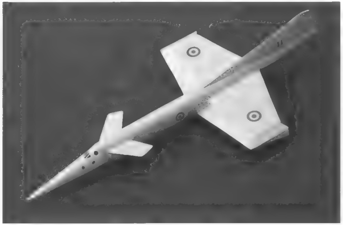
The wing surfaces ran uncut through the lower fuselage and then the body deepened and narrowed into a low aspect ratio fin designed to eliminate the conventional couplings that gave wing flutter. A shallow 'egg box' construction replaced the fuselage shell as the fin became more wing-like. The swept foreplane panels spanned 19ft 6in (5.9m), their gross area was 128ft^2 (11.9m^2) and they were mounted as all-moving surfaces; the undercarriage was conventional tricycle. Take-off with full fuel was considered practical only when the P.10 was mounted on a rocket-boosted trolley similar to the French Baroudeur fighter but a light fuel load take-off followed by in-flight refuelling presented no difficulties and was seen as the main method. P.10 had two crew, pilot and observer/navigator, two sideways-looking 30ft (9.14m) Red Drover aerials on 'KU Band' placed along the inside of the bottom of the centre fuselage and a Doppler aerial ahead of the nosewheel compartment.

In contrast to the turbojet, the ramjet lent itself very well to a wing-based installation since it had no moving parts and was not restricted to a circular cross-section thus making full use of the flow area through the wing. A great gain was that powerplant weight was made up solely of sheet metal burners, exhaust nozzle and fuel system because the walls of the ramjet and its intake were wing structural items. The required cruise at supersonic speed was of such overriding importance that the propulsive system was designed essentially for this condition. Here air was compressed in an efficient multi-shock intake in the wing leading edge and then diffused to very low subsonic speed in a diffuser. At the end of the diffuser were the ramjet burners where the fuel was injected and the flame stabilised.

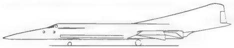
In cruise the ramjets ran at very weak fuel/air ratios and only about one-sixth of the total air flow was actually used for combustion. Hence, during cruise at 70,000ft (21,336m), the ramjets were only producing about one quarter of their maximum thrust so a huge margin was in hand for evasive manoeuvres. The rest of the air bypassed the burners and mixed downstream while, after leaving the combustion chamber, the gases were exhausted through a two-dimensional convergent-divergent nozzle. The drawing shows that the wing cross-section was divided into a number of triangular ducts, each with its own burner. By injecting extra fuel upstream of the cruise burners and using the variable nozzle, the ramjets were capable of developing a reasonable level of thrust for subsonic flight.

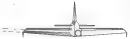
The point where thrust and drag were most likely to be critical was near Mach 1.2 at 36,000ft (10,973m) and it was estimated that ramjet thrust alone would equal drag at this point; thus the extra thrust provided by the two turbojets was sufficient for providing acceleration at Mach 1.2. These auxiliary jets, developed RB.123s of 32in (81.3cm) diameter mounted low in the rear fuselage, derived their air from wing ducts and exhausted through the wing trailing edge. Their main role was to provide thrust for take-off but they were also available for low-altitude cruise after mission completion. Immediately after refuel, the ramjets would be lit to continue a subsonic climb to 36,000ft, the tip tanks providing all the fuel used up to this point. Acceleration to Mach 1.75 at 36,000ft was seen as the next stage before climb and acceleration to Mach 3.0 at 70,000ft (21,336m). After a full fuel load take-off, it was just possible to accelerate to a speed at low level at which the ramjets could be lit – a ramjet cannot be used when the aircraft is at rest.

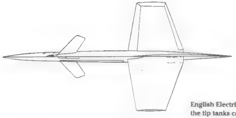
EE predicted that, from an early contract date, first flight could be expected in mid-1961 with service entry in third quarter 1964. Total internal fuel was 8,375gal (38,080lit) which EE felt was sufficient for the 5,000nm (9,265km) range. Ceiling was 85,000ft (25,908m). R.156T had requested that no detail consideration be made for bomber applications but EE suggested some sketch bomber designs based on the P.10 which assessed the structural and performance penalties of carrying various sizes of ballistic bomb.



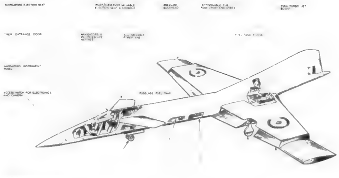
Model of the English Electric P.10. The ramjet wing is well shown but the winglet tip tanks are not fitted. Ken Hunter Collection



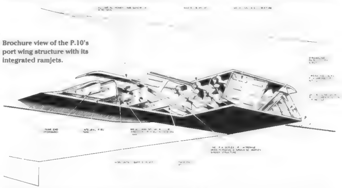




English Electric P.10 (5.55). An outline of the tip tanks can be seen plus the pipe for one auxiliary jet engine in the half-rear elevation (right).



Part cutaway showing some of the P.10's equipment.



Brochure view of the P.10's port wing structure with its integrated ramjets.

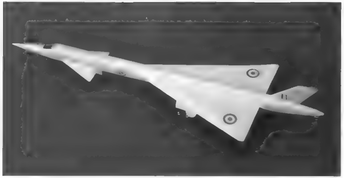
Handley-Page HP.100

HP's variation on the canard theme was a delta wing type designed to cruise at Mach 2.5 at a mid-range height of 65,000ft (19,812m). A detailed study of many different layouts showed that range performance remained substantially constant between Mach 2.0 and 2.5 but cruise above 60,000ft (18,288m) was essential to reduce the risk of interception.

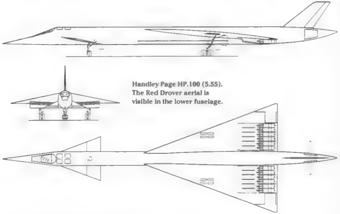
Existing light alloy structures were satisfactory for speeds up to Mach 1.8 or 2.0 but for Mach 2.5, steel or titanium was essential unless elaborate heat insulation and cooling was used. The HP.100 employed sheet steel construction but development time would be cut to a minimum by applying the welded and riveted corrugated sandwich panel technique used so successfully on the Victor. Mach 2.5 cruise demanded a structure capable of functioning satisfactorily with skin temperatures of about 230°C; most of the structure was designed for soak temperatures of 250 to 270°C but items such as landing gears and power control units, containing materials or fluids unable to withstand high temperatures, were located in cooled compartments.

HP.100 was designed to fly in the early stages of its development programme with a range limit of 4,000nm (7,412km). The planned programme was project design and tunnel testing completed in December 1956 and June 1957 respectively, aerodynamic design in June 1958 and detail design the following September. First flight would be in mid-1959 and service entry fourth quarter 1964. Developments including more efficient engine intakes, a structural change from steel to titanium and the provision of instrumental longitudinal stability would extend range to 5,000nm (9,265km) without flight refuelling. HP assumed there would eventually be a requirement to use this aircraft as a supersonic bomber with the ability to carry powered or ballistic missiles. A wide-spaced undercarriage and high ground clearance allowed carriage of both types beneath the fuselage; powered missiles could also be carried above the fuselage. As a bomber carrying a 12,000lb (5,443kg) external store, HP.100 had a range of 4,800nm (8,894km) at Mach 2.5 and a cruise height of 65,000ft (19,812m) over a target.

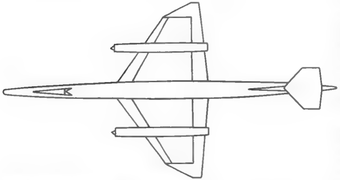
A detailed study of many arrangements including tail-first, tail-last and tailless, plus wings of various planforms, showed that the tail-first slim delta of the HP.100 with aspect ratio 1.46 had an excellent range/load performance and good inherent handling characteristics; foreplane span was 24ft (7.3m) and gross area 400ft^2 (37.2m^2). The highly swept sharp-nosed leading edges caused a flow pattern over the wing which remained substantially unchanged throughout the speed range thus ensuring no sudden changes in control and stability. A retractable visor was fitted which, when lowered, ensured that the pilot



View of John Hall's model of the Handley Page HP.100.



Handley Page HP.100 (5.55). The Red Drover aerial is visible in the lower fuselage.



Plan view of the Short P.D.12 (5.55).

had an adequate view for take-off and landing; when raised it gave a good aerodynamic shape at the fuselage nose for supersonic flight.

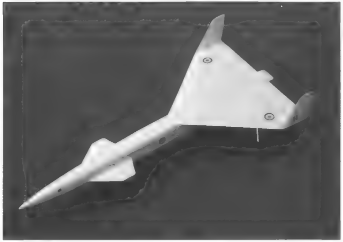
HP.100 had 12 RB.121 engines; other studies had used existing types like the Gyron with which it had proved almost impossible to meet the requirements of R.156T. Six RB.121s in three pairs were installed on each side of the aircraft in wide nacelles on the underside of the wing at the trailing edge – alternatives such as fuselage installations, vertical banks at the wing tips and pods were rejected. Vertical banks in particular were found to have adverse effects on stability and gave high drag; the HP.100's arrangement had low drag, no effect on stability and ensured a smooth airflow into the intakes at all usable wing incidences. A simple supersonic intake with fixed geometry had been chosen initially to help achieve an early flight date because it required no complex mechanical development and represented the type on which most work had been done in both the UK and USA. An alternative installation of four large Armstrong-Siddeley P.159s in the underwing nacelles resulted in an extra 2,000lb (907kg) of weight plus increased nacelle drag.

The radar comprised two side-looking 50ft (15.24m) 'X-band' Red Drover linear array search installations with mirrors in the lower centre fuselage, plus a single Doppler system for ground speed and drift. The crew comprised two pilots and two rearward-facing navigators and 16,875gal (76,729lit) of fuel was carried internally. Normal take-off wing loading at 205,000lb (92,988kg) was 82lb/ft^2 (400.3kg/m^2), altitude 1,000nm (1,853km) from base was expected to be 61,800ft (18,837m) or, after a zoom climb from the cruise path, 80,000ft (24,384m) at Mach 1.76. In fact 100,000ft (30,480m) could be exceeded with a zoom climb. Range at altitude and Mach 2.5 was 4,050nm (7,505km), increasing after development to 6,020nm (11,155km) with air refuelling; range at sea level was 2,100nm (3,891km). An HP.100 mock-up was built.

Short P.D.12

To the MoS, this project did not represent a formal tender; it was more of a study into the aspects and problems of flight at high supersonic speeds and appeared to present a design for a research aircraft to examine these problems. Presenting a relatively conventional design with engines in mid-wing

Model by John Hall of the Vickers R.156T.



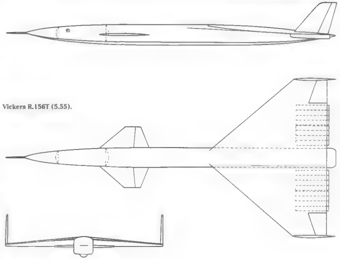
nacelles and a T-tail, the brochure lacked detailed information with little on equipment fittings. Construction was in stainless steel with the main powerplant of four Bristol BE.36 engines in two nacelles with two de Havilland Spectre rockets providing extra thrust for take-off; the X-band Red Drover aerial was 53ft (16.15m) long. Maximum height was 60,000ft (18,288m) with cruise height 1,000nm from base 57,000ft (17,374m), maximum range 3,550nm (6,578km). Service entry would be first quarter 1963.

Vickers R.156T

Vickers' proposal employed conventional light alloy construction and only required the development of existing plant for manufacture, an approach that made possible a first flight by the end of 1960. Retaining light alloy was necessary because of the time, expense and education needed when using a new material. This had led to an aircraft designed to suit the temperature rise of a conventional structure which gave a limiting speed of Mach 2.3 in the altitude band of 57,000 to 74,300ft (17,374 to 22,647m), its maximum height. The project was the outcome of an exhaustive investigation into supersonic aeroplanes during which some 50 projects were studied including unswept, delta, circular, arrowhead and cranked-wing planforms. Performance comparisons of conventional and canard layouts in conjunction with different wing planforms revealed that, in each case, the best canard configuration was capable of some 10% more range than the best conventional version.

Unless a very large tailplane was used, a supersonic aircraft had a nose-down pitching moment in the cruise condition due to the transonic rearward shift of aerodynamic centre. In a conventional layout this nose-down pitching moment had to be balanced by a down load on the aft tailplane, the wing had to carry an extra load and the induced drag was thus increased. In a canard layout the balancing load of the foreplane was in an upward direction, relieving the wing and reducing the induced drag.

The result was a canard layout with a still air range without flight refuelling of 4,405nm (8,162km), rather better than the reduced specified minimum; the standard 5,000nm (9,265km) was possible with flight refuelling some 300nm (556m) from base. The chosen wing planform gave the following advantages:



Vickers R.156T (5.55).

i. A reasonable landing attitude, achieved by limiting aspect ratio to a minimum of two.
ii. Maximum range through a combination of low structure weight and low drag.
iii. A relatively large volume for stowage.
iv. The smallest and smoothest movement of aerodynamic centre with Mach number.
v. Very low drag in the transonic speed range where engine performance was poor, thus ensuring good acceleration and climb performance in this region.

Studies showed that a large increase in all-up-weight was required for a small increase in range; conversely, should a range of 3,500nm (6,486km) be considered satisfactory then an all-up-weight of only 123,000lb (55,793kg) was required, resulting in a cheaper aircraft that could be produced quickly and more easily. Low-speed models of this configuration had been tunnel tested while a series of rocket tests were in progress to obtain supersonic data; high-speed and supersonic tunnel

testing would begin towards the end of 1955 with the engine intakes tested at Rolls-Royce Derby. Twin fins, one above each wing tip, were preferred as the foreplane's wake would spoil the flow over a central fin. No wing flaps were fitted since their provision would necessitate boundary layer control of the foreplane for trimming the aircraft with flaps deflected. Foreplane span was 24ft 3in (7.4m) and gross area 367ft² (34.1m²).

RB.121s were used because they offered low installation weight, low specific fuel consumption and made it possible to partially bury engines in the wing for low installation drag. Napier's P.191, Bristol's BE.36, DH's PS.38 and PS.48 and Armstrong Siddeley's P.159 were rejected. It was appreciated that using 16 engines under the wing trailing edge brought complications but Vickers felt there were more gains from this format. The engine controls were simplified by dividing the powerplant into four banks, each bank comprising four engines, allowing all the engines of a single bank to be operated as one unit. Investigations had shown that the two-dimensional 'letter box' intake with wedge-type centrebody was superior to the more widely known circular intake with a conical centrebody. A double-wedge type centrebody promised even better results since this required only three changes of angle for the second wedge throughout the Mach number range 0 to 2.3, thus avoiding the mechanical complexity of a continuously variable centrebody. Take-off was conventional but, above 27°C, RATOG would be employed in the form of two Spectre rockets.

The Red Drover aerial was 50ft (15.24m) long. For vision the pilot used a periscope but, in the event its failure, a window on the port side could be opened out to 45° at speeds below 230mph (370km/h) as an emergency visual landing measure. Hiduminium RR.58 aluminium alloy was chosen as the principal structural material instead of titanium or steel. Problems with the supply of the new 'wonder-metal' titanium so early in its development were likely to prevent an early in-service date, while the difficulty of fabricating a large aircraft of this type in high-grade stainless steel remained formidable and would involve a thorough revision of tooling methods. Aluminium offered a lower structure weight; a titanium alloy wing would be 18% heavier and a steel wing 30% heavier than a light alloy version, with an accompanying 'snowball' effect on all-up-weight.

As far as possible, machined integral panels were to be used for the main components and Vickers would gain experience in this type of construction with the Viscount Replacement before R.156 manufacture began. For the wing, a machined surface structural box would be built with multi-spanwise webs and ribs, the box to be kept as large as possible to keep both torsional stiffness and tankage at a maximum, the foreplane would use similar construction. Internal fuel totalled 14,550gal (66,157lit), no weapons were carried and the undercarriage used a four-wheel main bogie plus a nosewheel. First flight was predicted for December 1960 with service entry in first quarter 1964.

Saunders-Roe

Saro's R.156T work came under project number P.188 and comprised three preliminary studies, two utilising a total of 16 RB.121s either mounted across the upper wing or in large wing tip nacelles while an alternative configuration had four RB.122s, two of which were mounted on the fuselage and two at the wing tips. No brochure was tendered.

Several highly advanced British military aircraft programmes were under way during 1955 but R.156T/OR.330 was the most complex and potentially the most difficult of the lot. Throughout the summer, a great deal of time, effort and paper was expended on assessing which tender was best; the final report totalled over 250 pages. For example, in August, the National Gas Turbine Establishment (NGTE) reported on EE's ramjet proposals.

NGTE explained that in terms of efficiency, for example in saving weight and drag, the possibilities of engine/airframe integration offered by the ramjet had been recognised even for short-range missiles but had generally been avoided until now because other layouts offered apparently simpler development problems. P.10 was a logical, or even obvious, way to use ramjets. The traditions and habits developed over many years with other types of engine would die hard and the fresh thinking so evident from EE was welcomed. However, despite the obvious attraction of the general principle, there was little practical evidence to support it and careful detail study was needed to see if the possible gains were likely to be achieved. Here NGTE was disappointed by EE's brochure which did not discuss the major technical and engineering problems inherent with this system, problems that were novel, considerable and unpredictable.

More generally, the concept of the weapon system was apparently misunderstood by some companies. For example, choosing a canard was seen as a step taken by the aircraft industry primarily to overcome aerodynamic difficulties rather than to provide the greatest benefit to radar reconnaissance equipment. Only one company gave any thought as to how the aerial would be tested electrically and mechanically. From the radio aspect, the HP.100 was most favoured because HP had treated this area in far more detail and the arrangement offered potential for improvement and development within the aircraft. Avro was a close second having tackled the radar reconnaissance aspect fairly realistically, presumably because the company was fitting an experimental Red Drover into a Vulcan for the Royal Radar Establishment (RRE). The 730 offered slightly less room for development than the HP.100. Vickers got third place with English Electric and Shorts nowhere, but the assessor observed that 'it would appear that aircraft companies at present lack sufficient electronic knowledge'.

The Air Staff's operational analysis concluded that Vickers could be ruled out because it had chosen light alloy, thus restricting speed to about Mach 2.0 and limiting the prospects for speed development. P.10 was ruled out because it would not be in service until 1965 while its low all-up-weight was achieved only by reducing the length of the aerial system below an acceptable limit and making inadequate allowances for equipment. However, this design was most attractive and could form a suitable basis on which to meet a future requirement. Insufficient information was supplied by Short Brothers to assess the P.D.12 in detail, the company failed to meet the range despite deleting 3,000lb (1,361kg) of equipment and was ruled out because there was no prospect of meeting the timescale.

The Air Staff's estimates saw Avro and HP competing for first place with a comparable speed and height performance, but the 730 had the better range, meeting the 5,000nm (9,265km) limit in full without flight refuelling. HP.100 would only just meet the minimum 4,000nm (7,412km) until it was fully developed. Both could be modified to carry a bomb and their timescales were virtually the same but past experience indicated that Avro was far more likely to meet the forecast date. On balance the Avro 730 appeared the more attractive.

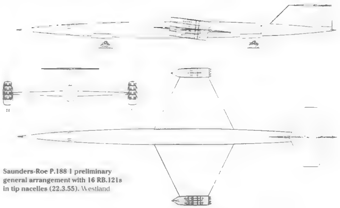
The Tender Design Conference was held on 13th September 1955 and chaired by G W H Gardner, DGTD(A). Short Brothers' P.D.12 was dropped immediately since it did not constitute a formal tender and failed to give the contractually required information. Air Commodore Kirkpatrick, DOR(A), said that

the P.D.12 was not attractive to the Air Staff because of, amongst other things, its deficiency in range, while Nicholson of RAE felt this was due to an inadequate matching of engines and airframe. P.D.12 had no outstanding technical or operational merits despite possibly employing experience gained with the Bristol 188. Kirkpatrick also reported that, due to its short range, the Air Staff now ruled out the HP.100.

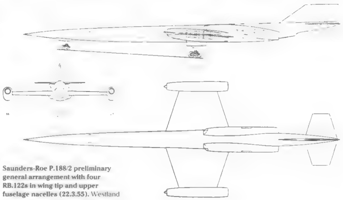
Morien Morgan of RAE explained that his team preferred the general configurations of the Avro 730 and Short P.D.12 although the wingplan of the HP.100 was of long-term interest. The 730's design was thought to be the best with its type of powerplant installation offering more flexibility. There was some opinion that canard layouts would present serious problems but Morgan thought that difficulties would be encountered whether the tailplane was at the back or the front. It was true that the Americans had run into troubles with canard guided weapons but these had largely cruciform configurations and the difficulties had been at higher incidences than need be necessary on an aeroplane.

Morgan stressed that the relation between thrust and drag was extremely critical and any marginal inaccuracies would have a very large effect on range. The P.10 had interesting features but had achieved its small size only by omitting equipment; had it carried the full load, its weight and size would have been comparable with the others. Its main attraction was its propulsion system, rather than the basic design, but Morgan was not convinced that the two-dimensional array of ramjets was necessarily more efficient than having ramjets in pods. The development time for ramjets, and for a method of take-off, might be long and RAE considered it would be most unwise to rely solely on this design to meet OR.330. The OR involved technical advances that were not only substantially greater but also much more complex than had ever been undertaken in one step before.

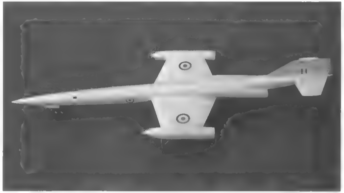
Nicholson reported that the ranges, as estimated by RAE, were much less than those claimed by the companies – the Avro 730's was some 3,700nm (6,856km) but the HP.100 and Vickers designs came out at 2,400nm and 2,650nm (4,447km and 4,910km) respectively. With minor changes the 730 might achieve 4,000nm (7,412km) but neither the HP.100 nor Vickers was likely to reach even 3,000nm (5,559km), despite efforts to stretch range including shifting the CofG in flight, overloading the aircraft and accepting lower



Saunders-Roe P.188/1 preliminary general arrangement with 16 RB.121s in tip nacelles (22.3.55). Westland



Saunders-Roe P.188/2 preliminary general arrangement with four RB.122s in wing tip and upper fuselage nacelles (22.3.55). Westland



John Hall's model of the Saro P.188/2.

flight factors, and reducing the operating height (a reduction of 1,000ft to 2,000ft [305m to 610m] might improve range by up to 10%). Beer and Turner of A&AEE, Boscombe Down, preferred some features on the HP.100 but confirmed that the 730's range was superior.

There was much thought on whether to allow for weight increases with extra equipment or to freeze the design early on. For example, Air Commodore Evans said that no one firm had seriously catered for Radar Countermeasures (RCM) when, for operations in 1964 and beyond, such equipment would be more necessary than ever. But Dr. Robert Cockburn pointed out that these aircraft would be operated in ones and twos and their RCM could not saturate the enemy's defences without a prohibitive penalty. Controlling weight growth would clearly be a major development problem. From the reconnaissance and navigation aspect, P.10 was quite unacceptable because so much equipment was omitted, but no firm had fully covered an integrated control system or paid any attention to an accurate alignment of the Red Drover, Doppler and Gyro system. By discarding so much equipment, RRE questioned the attitude of English Electric to the weapon system concept, apparently regarding themselves as experts in the radar field when Avro was willing to be advised by specialists. Avro was the only company to cater for all the equipment.

Structurally, Avro's 730 showed the simplest overall conception but, production wise, introduced a new field. Low temperature brazing was seen as the right approach to steel sandwich construction and was probably an inevitable future technique, but of the designs submitted it posed the biggest problems. Finally, all of the companies had made quite inadequate provision against the effects of kinetic heat and it was clear that much re-engineering would be necessary with an inevitable effect on weight. The preference was for the Avro 730 best meeting the specified requirements but the EE P.10 concept had attracted considerable interest because of its greater potential performance. It was felt that the P.10 could reinforce the 730 or be developed to future requirements or as a research aircraft.

Assessment had been wholly confined to the OR.330 reconnaissance role but on 6th April 1955 Air Marshal Pike, DCAS, had suggested the possibility of adapting the aircraft for bombing. (Even during the original tendering period, suspicion had grown that the OR.330 target date for service with the V-bombers was unlikely to be met and the possibility of using the aircraft as the basis for a V-bomber successor was considered.) For OR.330, Kirkpatrick said that the Air Staff had little option but to accept the Avro 730 although it fell short of the full requirement. Now bombing would also be required but the 730 had been selected without any actual reference to its ability to carry a bomb. G W H Gardner, DGTD(A), explained that the primary requirement was changing from reconnaissance to bombing and Gp Capt H N G Wheeler, DDOR, revealed that a bomber must be available not later than 1964 as a successor to the V class.

The date now forecast for service release, 1964, disappointed the Air Staff and it was hoped that the time to first flight could be shortened by about six months. E T Jones, PDSR(A), said one of the first things Avro would wish to do would be to build some flying scale models, but whether they should be subsonic (with a short development time) or supersonic (much longer) remained undecided.

Thoughts turned towards what to do with the P.10. Jones felt he could not support it as a research project since, in present form, it was too big while its Mach 3 speed was much below the Mach 5 research aircraft for which he was seeking industry interest. Kirkpatrick said that the P.10 concept scaled up and carrying a powered bomb would go a long way towards meeting the new OR.336 (a follow-on requirement described shortly) and, if developed from now, would have the right three-year time separation from R.156. It was concluded that Ministerial approval be sought for separate contracts to Avro and EE to cover two years of Research and Development of a supersonic reconnaissance-bomber system. This followed American procedure for continuing designs for two years when the rate of expenditure was relatively low to remove the difficulty of judging between them early on. In addition, a further contract would go to Avro to meet an amended OR.330 for bombing and another to EE to further pursue the advanced aspects of the P.10.

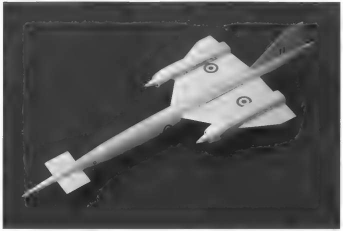
On 12th January 1956 EE reported that extensive tunnel testing had shown that the P.10's lateral and longitudinal stability characteristics were much better than initially found on the P.1 supersonic fighter and little improvement was needed to make them as good as the P.1 today after several years' work. At low speeds there were no serious problems from the canard arrangement and the fish-tail fin shape had proved even better than expected. Bomber roles had not been considered in the original brochure but aspects of a bomber P.10 had now been examined despite a lack of weight and geometric data being available for any new bomb. However, work on the P.10 did not progress much further.

A £25m contract was placed with Avro on 11th November 1955 for the preliminary design and supply of development aircraft to R.156T; the project received 'Superpriority' status to help obtain the necessary raw materials. Work was under way on the prototype by the end of 1955 but there were soon necessary design changes through the need for more powerful engines and to accommodate bombs. On 18th November A E Woodward Nutt stated that no engine, either existing or already under development, satisfactorily matched the performance required of the aircraft. Thus, competition to re-engine the 730 had by 24th January 1956 passed to the engine companies who offered three possible alternatives:

i. A new 38.5in (97.8cm) diameter engine, the Armstrong Siddeley P.176/2.
ii. A new 37.5in (95.3cm) diameter engine, the Rolls RB.127.
iii. A 48in (121.9cm) diameter heavily redesigned development of the de Havilland Gyron, the PS.26-4.

The MoS's R H Weir concluded there would be a substantial aircraft performance penalty using six PS.26-4s compared to eight P.176/2s or RB.127s but there was little to choose between the performance of the latter pair. Unlike the others, it was also not possible to test the PS.26-4, complete with its air intake, under free-jet conditions in the new Engine Test Facility at NGTE Pystock so, despite the benefits of the prior existence of the basic Gyron and its development running to date, the decision favoured a smaller engine.

Weir continued: Rolls-Royce had been studying the supersonic engine for a long time gaining much experience in intake and exhaust systems while being by far the most advanced company in practical experience of the cooled turbine, an essential feature of the engine in question. But Armstrong Siddeley Motors (ASM) now had a lively appreciation of the problems involved and, although less advanced than Rolls on practical experience of cooled turbines, the first Sapphire 8 had run some months ago and should rapidly supply experience from its development for the Gloster Javelin fighter. Technically, ASM had been in the unfortunate position of 'making the running' for the Avon with its Sapphire but the only disappointment was the company being rather late with a cooled turbine version of the Sapphire (which was in common with many companies on both sides of the Atlantic).



John Hall's model showing how the Avro 730 would have looked had it been built.

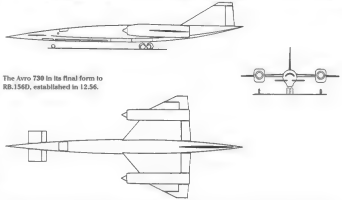
Weir felt both companies were capable of undertaking the design and development of the Avro 730's new engine. Technically, Rolls had the edge but two points favoured ASM.

a. The company's lower workload than Rolls, particularly now that Conway development up to Stage 4 was firmly established with the engine to be fitted into the Victor and/or Vulcan.
b. The company's close association with Avro through common membership of the Hawker-Siddeley Group.

On balance, he recommended that ASM should be given contract cover to design and develop the P.176/2 for the Avro 730, and this was approved.

P.176 was a single-shaft engine with a ten-stage axial flow compressor and a two-stage high-temperature turbine with air-cooled rotor and stator blades. It was intended for use with a variable geometry supersonic intake and a variable area convergent-divergent propelling nozzle. Maximum sea level thrust was 14,000lb (62.2kN) and it was designed to give 4,500lb (20kN) thrust at 60,000ft (18,288m) when flying at Mach 2.5. The eight-stage compressor RB.127 was rated at 12,600lb (56kN) at sea level and 4,530lb (20.1kN) at Mach 2.5/60,000ft; the seven-stage PS.26/4 Gyron had equivalent figures of 20,000lb and 6,055lb (88.9 and 26.9kN). P.176 was the lightest at 2,757lb (1,251kg), mainly by having a titanium compressor; the RB.127 weighed 2,942lb (1,334kg) and the PS.26-4 4,280lb (1,941kg).

By April it was hoped to fly a P.176 subsonically in a Vulcan at the end of 1958 and the 730 was expected to fly in December 1959. After the 730 was cancelled, ASM looked at ways of keeping the engine alive including awarding a licence to Curtiss-Wright in America to which the Ministry did not object. But the Ministry's support for the engine was cancelled in 1957 and its detail design was never finished.



The Avro 730 in its final form to RB.156D, established in 12.56.

Avro 730

In the ten months after contract award and the introduction of bomb-carrying capability, Avro sought ways of reducing the 730's basic weight. For a supersonic aircraft with extended range the payload was about 5% of the all-up-weight (an increase in payload was reflected by a twenty-fold increase in all-up-weight), so the company concentrated on possible payload reductions. Avro now proposed a crew of two only, pilot and navigator seated side-by-side, which involved repositioning the navigational and blind bombing displays in a scheme that reduced the payload. This also eased the structural problems of providing an adequate escape hatch and reduced the length of the crew compartment, thereby either reducing the fuselage length or making available more space for fuel.

It also became possible to carry a smaller bomb since the development of nuclear weapons had advanced to a short case megaton store for carriage in a reconnaissance-type aircraft. Hitherto, to fulfil the bomb-carrying part of the requirement, the 730's design had been based on carrying the experimental Blue Rosette store armed with a Green Bamboo warhead. A store weight of 7,000lb (3,175kg) was assumed, which itself had now dropped to nearer 6,000lb (2,722kg), but Avro had also learnt of the existence of the Orange Herald A-bomb warhead which would give a store weight of 3,500lb (1,588kg). From now on the 730 would be based around the smaller weapon but Avro felt it was wise to provide a bomb bay large enough to take the bigger store if required.

The size of the 730 was affected by the P.176's dimensions. With the changes to crew and bomb, Avro completed a full study of different variations of the same basic layout before choosing a final form in December 1956. The first issue of RB.156D for what was now a reconnaissance bomber had

been completed on 6th April (it was later renumbered B.156). For the 730, height when 1,000nm (1,853km) out was now 60,800ft (18,532m) and range with full internal fuel (take-off weight 292,000lb [132,451kg]) was 4,280nm (7,931km); fuel capacity was 21,000gal (95,485lit), maximum height 66,000ft (20,117m).

P.176 was finalised at 4,400lb (19.6kN) thrust at Mach 2.5 and 60,000ft (18,288m). Eight were fitted, four per nacelle, and the wing shape was much changed with sections added outboard of the nacelles. Since it had been possible to reduce Red Drover's length within an overall fatter fuselage (9.35ft [2.85m] maximum diameter instead of 7.5ft [2.29m]), a bomb bay was added behind the aerials for a 6,000lb (2,722kg) load comprising either the specially designed short-course weapon described above or the Red Beard tactical bomb. Canard span was now 19ft 7in (6.6m) and gross area 240ft² (22.3m²).

Avro 731

Following suggestions for a flying model, Specification ER.180D was raised on 9th September 1956 around the Avro 731 Scale Model Research Aircraft and it requested Mach 1.3 in level flight. The exacting performance requirements of R.156 had demanded the adoption of a number of novel features – tail-first layout, thin unswept wing, tip-mounted nacelles and central main wheel with outriggers. Tunnel testing indicated that the 730 would have satisfactory flying characteristics but there was no flying experience with any aircraft having any of these features and, after judging whether the design and development effort devoted to a model at the expense of the operational machine would be too severe, Avro considered that such a model would be beneficial.

The Avro 731 of December 1955 was a relatively simple three-eighths scale flying model that took every opportunity to use existing components and techniques in its construction. Three aircraft were proposed:

a. The first to explore take-off, landing and low-speed behaviour with special attention paid to developing high lift; it would fly towards the end of 1957 with existing jet engines.
b. The second flying in mid-1958 with more powerful engines using simplified reheat and capable of extending level flight into the low supersonic region at around Mach 1.3.
c. The third also flying mid-1958 with full reheat to allow short bursts up to Mach 1.8.

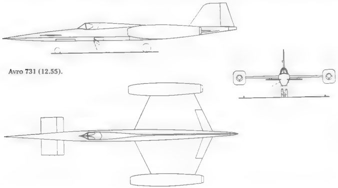
Two powerplants were considered – one Bristol Orpheus per wing tip nacelle or two Rolls RB.108s per nacelle. Although basically designed for VTOL aircraft, Rolls-Royce was planning to develop the RB.108 for applications in training aircraft.

Direct flight evidence could be obtained in many areas including the manoeuvrability at all speeds of the tail-first layout and general pilot familiarisation in the important low-speed phases of flight. The behaviour of a thin sharp-edged low aspect ratio wing at subsonic and transonic speeds would also be important. It was clear from tunnel tests that considerable regions of separated flow existed on wings of this type and the association of flow separation with buffeting had been demonstrated on existing aircraft. It was vital to know the extent of the associated problems as soon as possible.

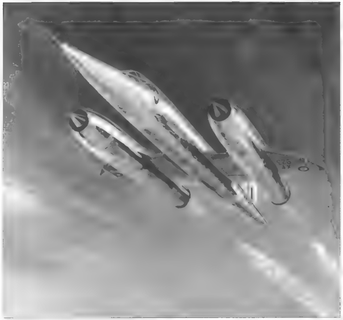
Aluminium alloy construction was to be used, the fuselage in honeycomb sandwich as used in the Avro 720 fighter; the 731's 'V' windscreen was a modified 720 type. The wing tip nacelles were to conform as near as possible to the 730's but here it was not achievable, with any of the suitable engines available, to make the nacelles exactly three-eighths scale. For the Orpheus, the engine was mounted in a monocoque shell attached to the main wing torsion box and the nacelle was made long enough to accommodate the 6ft (1.83m) of jet pipe required when the Bristol Simplified Reheat, or full reheat, was fitted. With two Orpheus 3s time to 36,000ft (10,973m) was predicted to be four minutes with maximum level Mach number (using Simplified Reheat) 1.4; four RB.108s gave 6.5 minutes and Mach 0.99. Canard span was 9ft 3in (2.8m), gross area 53.8ft² (5.0m²) and 458gal (2,082lit) of fuel was carried.

By 7th April 1956 the MoS was proposing up to four 731s with the first expected to fly in February 1958 and the others at three-monthly intervals – May, August and November; the Blackburn Buccaneer's Gyron Junior PS.43 engine was to be used. Avro also proposed PS.50 engines for the second and subsequent aircraft but this proved impossible because the special category engines to this standard would not be available before March 1959. PS.43s with moderate reheat would be as good and were to be developed as part of the PS.43 programme except that the variable nozzle had to be deflected for the 731. The PS.43 was to fly for the first time during 1956 in a Canberra test bed, one year before the first engines were expected for the first Avro installation.

A separate high-speed research programme had begun with the Rolls-Royce Avon powered Bristol 188 to ER.134D (described in *British Secret Projects: Fighters*). With a supersonic successor to the Gloster Javelin fighter under way (to F.155T OR.329), and the Avro 730, it was decided in September 1955 to order three additional Bristol 188 aircraft to accelerate these programmes. When it was established in February 1956 that the P.176's dimensions lent themselves to the 188's configuration, it was decided to adopt the engine for these additional aircraft so they could act as flying test beds for the 730 powerplant. Additionally, the 188 could assist the 730 with experience in steel manufacture and, to some extent, in aerodynamic control and kinetic heating, though it was realised that flight data would not be available in time to feed into the 730's design. In the end, delays to the Bristol 188, ironically from difficulties experienced in fabricating the stainless steel structure, prevented any data being made available to the Avro 730 programme.



Avro 731 (12.55).



Additional Bristol 188 research aircraft were to be ordered as flying test beds for the Avro 730's P.176 engine, but they were never built. The first 188 (XF923) is seen in an artist's impression before first flight BAe Filton

OR.336

On 12th January 1956, Kirkpatrick wrote that 'from 1965 we may have to give the OR.330 an extended life with a power-guided missile as per the V-bombers, but OR.330 was not designed to carry such a thing'. But in June 1955 a Draft Operational Requirement OR.336 had been agreed at Staff level for a Medium Bomber System to replace the Avro 730. Further developments of the V-bomber force were expected to maintain its effectiveness over the next seven years, but improvements to Russian defences would prohibit their operation after that. These could include a possible active homing, long-range SAGW capable of use against supersonic targets by 1964 and the possible introduction of supersonic all-weather fighters by about 1960. It was evident that reliance on the V-bomber system and its improvements as the main support of Britain's deterrent policy would become progressively less acceptable after about 1960 and probably quite unjustifiable in the period 1962-65.

It was therefore essential to strengthen the country's offensive power for that period and studies had shown that an effective long-range high-altitude bombardment system could be produced within ten years. OR.336 was to define the broad outline of such a system. Effective radius of action was to be 2,500nm (4,633km), operational height at all times when in reach of the enemy's defences 60,000ft (18,288m) and at least 70,000ft (21,336m) at the point of weapon release. Minimum top speed at altitude was to be Mach 3 and a ballistic nuclear weapon was to form one of two alternative loads along with an air-to-surface missile. It was to OR.336 that EE's P.10 was seen as a possible candidate.

A Supersonic Bomber Discussion Group met regularly from 27th June 1956 to consider a successor to the 730 having recognised that the very long development periods now needed for new aircraft meant such studies must start now. Despite the high-level requirement in the draft OR.336, the Group also analysed a possible low-altitude supersonic bomber and the delivery of nuclear weapons at low level; bombing techniques in general formed a major part of the discussions. The Group worked on the lines that a manned aeroplane would continue to occupy an important role in the deterrent threat and much of this later crystallised into OR.339, a document which raised for the first time a small war capability to go with reconnaissance and bombing.

The Group concluded that there was a need for a manned system to supplement the deterrent effect of the missile and provide a more economical bombardment system for limited war purposes. But its paper expressed the view that the considerable improvement to SAGW defences in the period 1965 to 1975 would put the manned air-breathing vehicle at a disadvantage in the struggle to gain enough height, speed and manoeuvrability against a contemporary missile system.

In February 1957 service entry for the Avro 730 was scheduled to be 1965 and manufacture of the first test fuselage was well under way at Chadderton. But in March the Air Staff completed an examination of the contribution which manned fighter aircraft could make to the defence of the United Kingdom, concluding that the major threat to the country was changing fairly rapidly from aircraft carrying nuclear weapons to one of ballistic missiles with nuclear warheads. This, of course, formed the basis of the famous April 1957 Defence White Paper which stated that the contribution future manned fighters could make was insufficient to warrant their development. As a result, the Saro SR.177 and Fairey F.155T were no longer required; only the Lightning survived to satisfy the short-term need.

At the same time, the Air Staff examined the problem of maintaining the deterrent and, in view of the increasing capacity of the Russian defensive system (including surface-to-air guided weapons), it was now considered most unlikely that the Avro 730 could survive during the period it would be operational. On 11th March, Air Commodore J F Roulston, now DOR(A), wrote: 'Since more certain methods of delivering nuclear weapons [missiles] are expected to be available in the same timescale, the Air Staff no longer requires the development of the aircraft to OR.330 nor any equipment peculiar to this aircraft'.

OR.336 was cancelled in April 1957 along with the Avro 730, the last meeting of the Discussion Group being held on 27th May. Roulston confirmed 'all that was required was an adequate deterrent, i.e. a threat to deliver thermo-nuclear bombs over long ranges. It was considered that ground-to-air missiles can always be developed to provide defence against aircraft at any time so that, after the present V-bombers, the threat would have to

depend entirely on Intercontinental Ballistic Missiles [ICBMs]. To maintain the threat, reconnaissance would not be required, and in the event of a short global war we would not be interested in reconnaissance. For small wars, OR.339 was the next step to provide both the required reconnaissance and bombing capability'.

In April 1957, H J Kirkpatrick, by then Air Vice-Marshal and ACAS(OR), wrote a paper explaining the future of manned bombers, doubts having been expressed as to the wisdom of cancelling the Avro 730. The decision was strongly influenced by new information on the effectiveness of SAGWs with nuclear warheads. There had been concern all along about the chances of survival against missiles with conventional high-explosive warheads but the possible availability of nuclear SAGWs in the timescale for which the 730 was expected to enter service led the Air Staff to conclude that the aircraft would have a low chance of reaching its objective. Therefore, since more certain methods of delivering nuclear warheads were now available in the same timescale, the Air Staff no longer felt justified in continuing the OR.330 project.

There was good reason to believe, however, that a low-altitude threat might be difficult to counter and that, although low-altitude operation might not be readily compatible with the reconnaissance requirement, a low-altitude bombardment system offered attractive possibilities. In fact the Air Staff now considered that it had tended to overrate the value of reconnaissance as a contribution to the main deterrent and there was no justification in proceeding with a project for a manned aircraft designed solely for this purpose in the 1965-75 timescale. The usefulness of a manned high-altitude bombardment system to supplement the deterrent threat of the Medium-Range Ballistic Missile was also considered and ruled out on the grounds of vulnerability to a nuclear-headed surface-to-air guided weapon and the enormous cost of developing such a system.

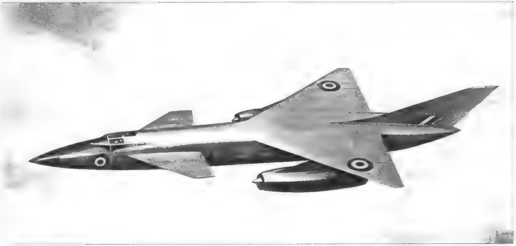
The manned high-altitude system might still have a limited war potential but its usefulness here could not alone justify continuing with the project, especially when this work could be done rather better by the sort of Canberra replacement Tactical Strike Reconnaissance aircraft now under consideration. However, after a further study made on his behalf, Kirkpatrick felt the Air Staff would not be justified in proceeding further with a project for a low-altitude bomber either. Actually, as the next chapter shows, that work was well under way and the first draft of General Operational Requirement GOR.339 had already been written.

Official records show that serial numbers were never allocated to either the Avro 730 or 731 and it is most likely that the 731s were never ordered; they were to be built by Armstrong Whitworth. Bristol's work on the 188 did continue but the three P.176-powered machines were also cancelled. Would the Avro 730 have been a success? The aeroplane was full of advanced systems and equipment and there was plenty of scope for problems. There was also concern about how well the aircraft could fly if it was damaged – would it be able to return to base? – and whether there would be sufficient stiffness in such a long slim fuselage. Finally, the all-steel Bristol 188 proved very difficult to build – would manufacturing the 730's structure have been an equally difficult task? The Avro 730 has left us with plenty of points to discuss.

OR.330 Bomber Projects – Estimated Data

Project	*Span ft in (m)*	*Length ft in (m)*	*Wing Area ft² (m²)*	*t/c %*	*All-Up-Weight lb (kg)*	*Powerplant Thrust lb (kN)*	*Cruise Speed / Height mph (km/h) / ft (m)*
Avro 730	59 9 (18.2)	163 6 (49.8)	2,000 (186)	3	222,660 (100,999)	4 x P.159 20,750 (92.2) + 2 rockets	Mach 2.5 at 60,000 (18,288)
English Electric P.10	70 0 (21.3) with tanks 50 0 (15.2) clean	108 9 (33.1)	1,310 (122) with tanks 1,050 (98) clean	14.5 root 12.5 tip	123,000 (55,793)	24 ramjet + 2 x RB.123 boosters	Mach 3.0 at 70,000 (21,336)
Handley Page HP.100	59 4 (18.1)	185 0 (56.4)	2,500 (233)	4	205,000 (92,988)	12 x RB.121, 81,600 (362.7) total	Mach 2.5 at 65,000 (19,812) Mach 0 95 at sea level
Short P.D.12	77 0 (23.5)	150 0 (45.7)	2,059 (191)	?	175,000 (79,380)	4 x BE.36 17,950 (79.8) + 2 x Spectre rocket	Mach 2.5 at c56,000 (17,069)
Vickers R.156T	63 3 (19.3)	133 0 (40.5) with probe	2,000 (186)	4	209,500 (95,029)	16 x RB.121 5,465 (24.3) + 2 x Spectre rocket	Mach 2.3 at 57,000 (17,374)
Saro P.188-1	63 6 (19.4)	151 0 (46.0)	1,500 (140)	?	170,000 (77,112)	16 x RB.121	?
Saro P.188-2	59 6 (18.1)	165 0 (50.3)	1,500 (140)	?	180,000 (81,648)	4 x RB.122	?
Avro 731	25 7 (7.8)	59 0 (18.0)	338 (31)	3	14,310 (6,409) or 14,246 (6,462) with RB.108s	2 x Orpheus 3 or 4 x RB.108	Orpheus Mach 1.4, RB.108 Mach 0.99 at 36,000 (10,973)
Avro 730 (Final form)	65 7 (20.0)	159 0 (48.5)	2,100 (195)	2.75	292,000 (132,451)	8 x P.176 14,000 (62.2)	1,650 (2,655) between 55,000 (16,764) and 70,000 (21,336), Mach 2.0 over 45,000 (13,716)

Canberra Replacement



Artist's impression of the attractive Fairey GOR.339. BAE Systems via RAF Museum

Tactical Strike Aircraft: 1951 to 1958

It is now approaching four decades since the TSR.2 was cancelled by the Labour Government yet arguments for or against that move remain as strong as ever. What cannot be denied is that the aircraft itself was a great technical achievement and one of the finest products of the British aircraft industry, taking its place alongside Concorde as the military and civil design peaks for the 1960s. The companion *British Secret Projects: Fighters*, describes how the 1957 Defence White Paper closed almost all future development on manned fighters, a step that ensured there was insufficient military work to occupy the whole industry. The only new project to survive was the 'Canberra Replacement' and most of the companies fell over themselves to tender for it. Actually, work had been ongoing for six years.

It was often Air Ministry practice to consider a type's replacement from the point it first entered service. When OR.302 was issued in September 1951 for a developed Canberra it was also thought to be an appropriate time to start looking at the type of aircraft that would be needed to replace it (the Air Staff would have been astonished to know that some Canberras still serve in 2001). On 22nd February 1952 Air Vice-Marshal Geoffrey Tuttle, ACAS(OR), wrote: 'Frankly, I do not believe that we will get much operational value out of the Canberra from 1955 onwards...the aircraft is already out of date and I doubt its chances of survival in daylight against present MiG-15 opposition'. Air Cdr H V Satterly, DOR(A), felt Canberra was 'clearly incapable of further development to meet the light bomber task'. A draft Requirement for a new light bomber to attack targets beyond the range of fighter-bombers was circulated in March 1952 but, although the Air Staff accepted the general concept, it was not regarded as a project of first level importance.

Throughout the history of the RAF larger and larger aircraft had been developed, with greater bomb loads and ranges, but there had also been a continuing need for a bomber which was smaller, cheaper and easier to produce than its heavy contemporary. Despite the fact that warfare was now conducted in greater depth than previously, the small bomber's primary role was still to attack enemy airfields, communications and troop concentrations, usually as part of the land/air battle. In addition, the recent Mosquito had been adapted to undertake further duties such as photo reconnaissance, night intruding and interdiction, target marking and shipping strikes. In an appreciation dated 27th May 1952, Sqn Ldr A J L Craig concluded that guided missiles or a planned expendable bomber could only fulfil a limited part of the offensive short-range task; a light bomber was still required.

Gloster Thin Wing Javelin

Suggestions to adapt the Thin Wing Javelin fighter for the role were made in January 1953 and OR.328 was allocated to it later in the year, but lack of funding meant progress was slow. The Air Staff intended to exploit the potential low-level performance of the Thin Wing Javelin in the bomber role and its max-

Blackburn Buccaneer development aircraft XK526. The Buccaneer features throughout the GOR.339 and TSR.2 story. BAe Brough

imum range at high subsonic speed would be 1,000nm (1,852km). The great difficulties of defending against low-altitude attack should allow a Javelin bomber to have a useful low-altitude operational life until about 1966 but its high-level capability would be limited by the short range (250nm [463km]) of its ground-based blind bombing aid and vulnerability to enemy defences during deep penetrations.

Gloster's approach was to adopt the fighter to OR.328 as closely as possible with minimal redesign, though meeting the full endurance was difficult. Deleting fighter equipment made space for 2,600gal (11,822lit) of internal fuel while drop tanks under the fuselage and one wing increased this to 4,000gal (18,188lit). Olympus 6 engines were fitted and a 'light' atom bomb would go under the other wing but the preferred 1959 in-service date would be missed by two years. However, in its 1955 annual review, the Defence Research Policy Committee (DRPC) recommended that OR.328 should be abandoned and on 11th April 1956 the document was cancelled.

In early 1953 English Electric considered a replacement of its own (a supersonic mid-wing type with engines buried in the wing roots) but more serious study concerned Blackburn's naval B.103 (Buccaneer). This was considered as an RAF tactical bomber in October 1955 but rejected. Satterly, now ACAS(OR), felt it was 'not much of an advance on the Canberra'. Since it was designed for low-altitude and subsonic performance, its high-altitude performance was 'handicapped by either lack of span or too early drag rise' and fitting new engines and modifying the existing wings would make service entry in 1960 impossible. It was clear 'that to meet our requirements in full, a completely new design is necessary'. It was also thought to have an insufficient chance of surviving enemy defences and Gp Capt H N G Wheeler added that the Buccaneer was 'simply not designed for the purpose and...barely exceeds in speed and target height the PR Mk.9 Canberra; it seems quite wrong to introduce in 1960 a subsonic aircraft that stands no hope of being supersonic'.

Progress on the Canberra replacement was slow, principally because most effort was concentrated on developing the strategic bombers to provide a deterrent. During 1956 however, the absence of the tactical aircraft type from forward planning became increasingly marked, especially so during the Suez episode, and support for it became much stronger. By now the situation had been reached, bearing in mind the eight years or so needed to develop a new type, where a Canberra successor could not be expected in service before 1965.

On 28th November OR.339 was recorded for a tactical strike and reconnaissance aircraft and by February 1957 all the Commands operating tactical air forces supported the low-altitude penetration concept. Only Bomber Command suggested that primary emphasis should be given to high-level per-

formance while the Army felt the project represented a tremendous advance on anything they had had before. During this period adaptations of the Saunders-Roe F.177 and Fairey 'Delta III' fighters were examined together with a VTOL low-level strike aircraft from Shorts. The Buccaneer was again rejected and one point raised by a joint RAF/MoS investigation was that a modified Supermarine Scimitar, costing only some £5m to develop, could meet the requirements of NA.39 for which Blackburn's aeroplane was being developed at a cost of £20m. The RAF really had it in for the Buccaneer and in August 1957 the Admiralty had to fight off an attempt to stop developing it for the Navy.

Time-honoured practice for providing tactical strike/reconnaissance aircraft for the RAF had been to take a front-line interceptor and dress it up with ground attack weapons as a fighter-bomber. In July 1957 Tuttle noted that such practice in the jet era alone made dismal reading. Early Gloster Meteors with the 2nd Tactical Air Force in 1945, and Meteor 8s in Korea, were relatively ineffective in the ground attack role through a lack of range and flexibility while 'today our Swifts and Hunters are gravely restricted in the fighter reconnaissance and ground attack roles overseas. A developed F.23 [Lightning] would be no better'. During the recent action in Egypt, the limited range of de Havilland Venoms meant they were operated on a sortie profile which gave maximum early warning to the enemy; against even moderate opposition, this could have had disastrous consequences. He concluded that a new and specialised aircraft was required to perform these functions (including tactical nuclear strike) with the ability to operate under any weather conditions at all ranges, day and night. Emphasis was placed on low-level capability since this posed the greatest defence problem to the enemy.

For the first time tentative features of a new type were set out in a General Operational Requirement, GOR.339 dated March 1957, though intimations had reached EE and Hawker a year earlier. Delays and problems in developing previous military aeroplanes had led to a recommendation for a broad GOR to be raised for issue to industry at an early stage. It was intended to enlist the assistance of several companies to suggest improvements before completing a more detailed OR.339, so that advantages were gained by getting industry involved much earlier than had been possible in the past. However, the White Paper delayed GOR.339's transmission to industry until September and then it went to many companies rather than just the two or three whose advice it had been hoped to solicit. Meanwhile, in spring 1957, knowledge that the RAF needed a tactical aircraft prompted some companies to submit 'interim' variants of current types.

Blackburn B.103A

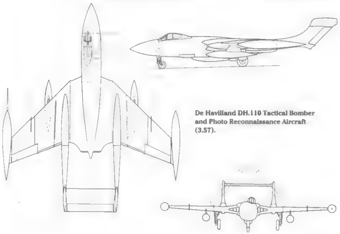
A simple modification of the NA.39 with integral fuel tanks inserted in the wings to replace the wing fold mechanism and a fuselage extension behind the rear cockpit for more fuel, the B.103A retained flight refuelling capability and had modified Gyron Juniors with 10% more thrust, but the same cruise consumption, as the PS.43. With total fuel increased by 300gal (1,364lit), take-off weight would be 48,000lb (21,773kg), radius of action 850nm (1,574km) and penetration speed Mach 0.85; it carried all the various loads of the B.103 and two additional cameras. B.103A would be available in 1962 at the earliest.

De Havilland Christchurch DH.110

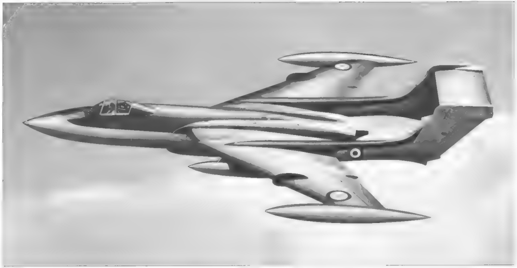
The 'DH.110 Tactical Bomber' merged two separate RAF and Navy brochures prepared during the autumn of 1956. Designed for both land and carrier operation, it made full use of the extensive experience already collected from the standard Sea Vixen with minimal changes. Tip tanks were permanently fitted but span was reduced by the tanks' width to keep overall span the same; further underwing tanks were carried and a fuselage extension behind the cockpit made room for another 850gal (3,865lit). With wing tanks, total fuel was 3,500gal (15,914lit). The aircraft would have a complete flight refuel system and act as a 'buddy' tanker to refuel other aircraft. Carrier operations would need a lower fuel load for take-off but flight refuelling afterwards would restore the full range.

To help airfield performance, flap blowing was installed along with extra droop on the leading edge inboard of the fence. Elevator area was increased as per the original DH.110 night fighter to F.4/48 and some wing structure was changed from DTD683 aluminium to more fatigue-resistant 24S steel. Wing folding and the arrestor hook were retained on the land version. The extra fuel gave a 550nm (1,019km) sea level radius of action, the last 200nm (370km) to and from a target being flown at Mach 0.87 (662mph [1,065km/h]); high-altitude operation increased the radius to 1,575nm (2,917km). A burst at Mach 0.95 in a dive was planned over the target area (dive speed limit was Mach 1.2 above 14,000ft [4,267m]).

The Vixen's RA.24 Avons were replaced by 13,880lb (61.7kN) RB.133s (a developed Avon) and an optional de Havilland Spectre rocket could be installed in a jettisonable pack between the two jets to assist take-off. Maximum take-off weight with a TMB partly submerged in a bay in the aircraft's belly, plus two drop tanks, was 59,960lb (27,198kg) (wing loading 97.3lb/ft^2 [475kg/m^2]); four 1,000lb (454kg) bombs carried on two underwing hardpoints and in the fuselage position increased this to 62,080lb (28,159kg) and alternative loads comprised 24 3in (7.62cm)



De Havilland DH.110 Tactical Bomber and Photo Reconnaissance Aircraft (3.57).



or 96 2in (5.08cm) rocket projectiles. Reconnaissance cameras were installed in the nose alongside the radar. Span was 50ft (15.2m), length 59ft 6in (18.1m), wing area 611ft² (56.8m²), wing t/c 10%, and top speed Mach 0.87. De Havilland intended building two prototypes in 1957 using standard Sea Vixen wings and engines to make possible an introduction into service in 1962.

Hawker P.1121

Hawker had put a great deal of effort into the single-engined P.1121 private venture fighter but little interest had been forthcoming from the Air Staff. P.1121 was due to fly in mid-1958 and this proposal was a tactical variant which Hawker claimed could serve both offensive and defensive functions. The company favoured the Conway 11R for offence rather than the fighter's Gyron PS.26-6. Take-off weight with the TMB under the port wing, 1,500gal (6,820lit) of fuel and 50 2in rockets in an internal retractable installation was 43,700lb (19,822kg); this became 48,200lb (21,863kg) when three more 150gal (682lit) drop tanks were carried to give a 700nm (1,296km) radius of action. The aircraft would be available in 1962.

Vickers (Supermarine) Type 565

This tactical Scimitar variant, begun on 21st February 1957, had a new nose to house a Blue Parrot search radar, two crew seated side-by-side, guns and ammunition replaced by fuel and an extra pylon under each wing, inboard of the undercarriage, which allowed a load of six 1,000lb bombs. Wing folding and arrestor hooks were deleted and 500gal (2,273lit) slipper tanks introduced to go with a flight refuelling capability. For nuclear delivery, a single bomb was carried under the port wing balanced by a 200gal (909lit) drop tank on the starboard side. Improved Mk.2 RA.24 Avons were fitted with an optional 8,000lb (35.6kN) Spectre rocket to assist take-off. Take-off weight with one TMB, 1,548gal (7,039lit) of internal fuel, one 200gal and two 500gal drop tanks was 48,570lb (22,031kg), penetration speed Mach 0.83 with maximum combat speed Mach 0.93, low-level range 670nm (1,241km) and high-level range 950nm (1,760km). Overall length 61ft 5½in (18.7m), span 37ft 2in (11.3m), and t/c 8%. Available in 1961, Type 565 would have been too heavy for carrier operations.

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These proposals were assessed in May 1957. All except perhaps the P.1121 would be available two years before GOR.339's required 1964 service entry, but their continuous operating speed and all-weather strike capacity was far short of the requirement; only the modified DH.110 had the 1,000nm (1,852km) range. P.1121 was unacceptable through its single crew, external stores and short range and, indeed, it was quite different in concept to a strike aircraft. It would cost as much as an all-new design when the other 'interim' projects were intended to be a lot cheaper. The rest had a penetration speed of Mach 0.85, not

Artist's impression of the 'interim' DH.110 with fuselage extension. BAE Systems

'339's 0.95, they lacked a short take-off capability and showed severe weaknesses in their ability to find a target; for example, the Sea Vixen development had a radar that was only really effective in good visibility. Neither the DH.110 or Type 565 offered solutions to the thermal problem of carrying nuclear stores externally (heat build-up from air friction).

There was also a query over 'early entry into service and low cost' since past experience showed such cases had produced serious underestimates of the design work involved. Examples quoted were the swept wing on the third N.9/47 fighter prototype (Supermarine Type 508 conversion to Type 525) and the third prototype F.23/49 (English Electric Lightning P.1B), the latter taking 17,000 man weeks to produce compared to the 16,500 taken by the P.1A. The B.103A's wings and fuselage implied a large drawing office task while changes to the DH.110 and Type 565 would also need a heavy drawing effort; a 'conversion' often took as much work as the basic aircraft. Clearing the DH.110 for RAF duty would need six development machines including one for RB.133 testing, but none of these aircraft would maintain the viability of the RAF in the tactical strike/reconnaissance role beyond 1965. They would not be capable of penetrating the expected defensive systems to strike at inland targets and so all were rejected in July.

GOR.339

The document noted that the advent of the hydrogen bomb had enormously strengthened the deterrent which decreased the likelihood of global war. However, limited wars were considered an increasing possibility and weapon systems in the tactical field should hence have the best possible limited war capability as well as meeting global war requirements. The Air Staff believed that the tactical strike reconnaissance requirements could be more adequately met by a manned aircraft weapon system because the ballistic missile, though possessing several advantages, was unsuitable for meeting Cold War needs, had no capacity for attacking unknown positions, nor a reconnaissance capability. In addition the missile was a most uneconomical method of delivering high explosive when required.

A self-contained all-weather bombing system was needed with adequate range to permit operations from the UK's overseas bases or, in global war, from outside the highly vulnerable tactical area. Actual independence from airfields was felt desirable but if runways were needed, take-off and landing distance were to be kept to a minimum to facilitate operations from damaged or dispersed strips. The Canberra was to continue providing the tactical strike and reconnaissance force for some time to come but how long it would be effective in the tactical role was unknown. However, operated at low level, the Air Staff felt it could continue for limited war use at best to 1965, in global war to 1963. Thus a tactical strike reconnaissance aircraft to conduct the tactical offensive was defined with the following roles in order of priority:

1. Tactical nuclear weapon delivery from low altitudes up to maximum range, day or night, with minimum consideration of weather conditions;
2. Photographic reconnaissance, medium and low level in day, low level at night;
3. All-weather electronic reconnaissance without compromising the nuclear delivery role;
4. Effective delivery of tactical nuclear weapons by day or night from medium altitudes under visual conditions or with blind bombing;
5. Effective delivery of high-explosive bombs or rockets under visual conditions.

The majority of the mission had to be flown at 1,000ft (305m) or less above the ground; an alternate medium-altitude capability offered more flexibility which was very desirable but must not compromise the low-level requirement. The aircraft would have no defensive armament and be independent of long runways, operating from 3,000ft (914m) strips. A 1,000nm (1,852km) radius of action was stated without flight refuelling with the final 200nm (370km) to and first 200nm from the target at low level (first draft GOR.339 had requested a 600nm [1,111km] radius which still featured during assessment). Penetration speed at sea level was Mach 0.95 minimum, ferry range 2,000nm (3,704km) and in-flight refuelling would be available. An additional supersonic dash capability was preferred.

Weapons included the Red Beard nuclear store and alternative secondary loads of four or overload six 1,000lb (454kg) bombs, 74 2in (5.08cm) or 12 3in (7.62cm) rockets. Bomb delivery would use a loft manoeuvre at low level or a dive toss attack from medium height. Crew comfort was particularly important with some form of gust alleviation needed to maintain tolerable conditions during long periods of high speed, low-altitude flight. By March 1958 further issues of GOR.339 had brought many changes, significantly some low-altitude flight at 150ft (46m) (500ft [152m] in blind conditions) and a minimum Mach 1.7 at the tropopause. Part of the sortie profile now included 100nm (185km) at Mach 1.7+. The aircraft had to be in service in 1964 or as soon thereafter as possible.

A September 1957 meeting between the MoS and the heads of all the major companies revealed that contracts would only go to groups of companies working together, the Government stating that this would be policy for any future aircraft plans (this was the first indication for amalgamating the individual companies). All submissions were to be made by 31st January 1958, eight companies plus the Hawker Siddeley Group being invited to tender. In the event, some of the submitted brochures did not give clear details of their company's working partners which counted against them during assessment.

Avro 739

Avro had favoured either a swept tapered wing or a delta but preferred the swept wing. Its studies were assisted by previous work on the Type 721 low-altitude and 730 supersonic high-altitude bombers, the latter providing knowledge in automatic stabilisation and control. The specified high sea level speed was a major design influence since it was essential to keep aircraft response to atmospheric turbulence at a level where the crew could perform satisfactorily. Avro stated that for a given level of gustiness, normal acceleration depended on forward speed, wing loading and some aerodynamic characteristics so, as forward speed increased, wing loading should increase accordingly to maintain the comfort level.

The 739 used conventional construction, mainly aluminium but with titanium in hot regions near the engine. The need for an efficient structure led to the main load-carrying

Model by John Hall of the Avro 739.

torsion box of the wing, constructed from panels integrally machined from slab, being taken right through the fuselage between the weapon bay and engines. The all-moving tail was mounted in the low position, essential for satisfactory longitudinal stability and control. Low-speed control came from ailerons, rudder and tail but at higher speeds the ailerons were locked so roll control was provided by differential movement of the tailplane which gave better rolling power at supersonic Mach numbers. Drooped leading edges and supersonic blowing over the deflected leading and trailing edges provided lift augmentation. Wing loading was 142lb/ft² (693kg/m²), a figure set by the toss bomb manoeuvre. Area-ruled, the fuselage used normal skin-stringer construction and housed the entire undercarriage because there was insufficient space in the thin wing.

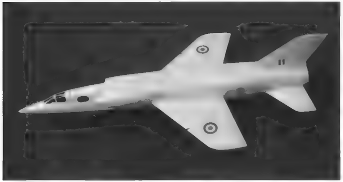
GOR.339 requested a supersonic dash at sea level but the direct effect of this was to increase structure weight. The defence against a GOR.339 type would be a radar-directed ground-to-air missile and both high aircraft speed and low aircraft altitude would reduce such a system's efficiency. It was expected that an increase in aircraft speed would, all other things being equal, lead to a rise in its height above the ground which might nullify any reduction in vulnerability. Avro understood that recent studies had indicated a speed of Mach 0.9 would give reasonable protection against ground-to-air defensive systems and the 739 was therefore based on a Mach 0.9 to 0.95 sea level cruise speed.

Fuel was housed in the wings, in large tanks above the bomb bay and in the lower rear fuselage; two extra 600gal (2,728lit) underwing tanks or a flight refuelling pack were available if required. A 600nm (1,111km) mission radius with 100nm (185km) at Mach 2, or 1,000nm (1,852km) all subsonic, was possible on internal fuel. The 1,000nm with a Mach 1.8 burst needed the drop tanks which would be jettisoned prior to supersonic acceleration. Sea level rate of climb at 70,000lb (31,752kg) weight was 10,950ft/min (3,338m/min); at 90,000lb (40,824kg) this fell to 8,100ft/min (2,469m/min).

Six engines were considered: the Conway 11R/3B and 11R/3C, Olympus 14R, 15R and 21R, and Rolls RB.142. The latter was a reheated military derivative of the RB.141 Medway bypass engine chosen for the DH.121 airliner which had a two-spool compressor and offered good cruise economy. Initial ratings were 14,000lb (62.2kN) dry, 22,700lb (100.9kN) with reheat (RB.141 was an entirely new design based on the Conway which was later dropped and replaced by the smaller RB.163 Spey). Ol.15R was an improved Ol.14R derived from the 200 Series production Olympus; it offered 24,700lb (109.8kN) reheated and, having two shafts, high compression and convergent-divergent nozzle, matched well the GOR's requirements.

For convenience the table quotes the RB.142R because most rivals chose the same. Each engine could take the 739 over Mach 2 at 36,000ft (10,973m) but, at that height, there was appreciable performance difference at Mach 1 to 1.5. The Conway 11R/3C (19,580lb [87.0kN] dry, 29,850lb [132.7kN] reheat) and Olympus 21R (18,800lb [83.6kN] 28,000lb [124.4kN]) gave 50% more acceleration, so maximum Mach at higher altitudes was correspondingly increased. The 'small' Ol.15 and RB.142 gave an aircraft up to 6,000lb (2,722kg) lighter than the 'heavy' Conway and Ol.21R.

The electronics included a nose-mounted 33in (84cm) radar dish and sideways navigational and reconnaissance aerials (X and Q-band): four vertical cameras could be carried in a pack fitting. The weapon bay, placed beneath the intakes, was designed around Red Beard which, after a forced ejection, was delivered by toss bombing, but Avro felt carrying a winged stand-off bomb part buried in the lower fuselage would be more accurate. Variable sweep and VTO were rejected because of longer development times and an alternative single-engine machine was discarded since engine failure away from base meant loss of aircraft; this would also need extra assistance on take-off. It was expected that 739's first flight would be November 1961 and 15 development aircraft would be completed during the next 33 months. A fighter derivative with Red Top missiles was briefly outlined as a suitable long-range interceptor to succeed the EE P.1.

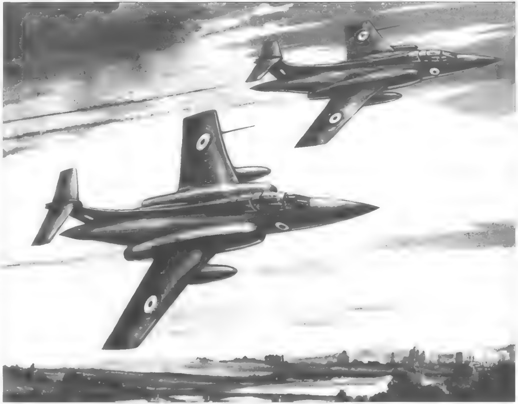


Model by John Hall of the Avro 739.

Blackburn B.108

This was a more extensive B.103 development than the B.103A although the modifications were kept to a minimum. B.108 departed in several ways from the GOR but the changes were felt to be acceptable when weighed against cost, time and the greater certainty of a satisfactory product. The new operational concept of high-speed low-level sorties introduced new problems in the aerodynamic and aeroelastic fields while Blackburn's work on the naval B.103 had also revealed difficulties with control and structural fatigue due to high turbulence at low altitude. Consequently the company felt its team had a unique understanding of these problems and the methods needed to overcome them.

Blackburn envisaged two stages of development, neither of which departed from the B.103's aerodynamics. Firstly, the basic airframe was increased in length by 18in (46cm) and in weight by 800lb (363kg) to accommodate a new two-seat cockpit, a new sideways-looking J-band navigation radar and a second forward-looking set for terrain-following. Naval fittings were retained and photo reconnaissance gear was housed internally. With large drop tanks to supplement the internal fuel, GOR.339's maximum ranges could be met, bar the 1,000nm (1,852km) limit, but in-flight refuelling was also available. Wing loading was 98lb/ft² (478kg/m²). These changes were offered as a low-cost alternative to an all-new supersonic design and were to be followed by the second stage offering considerable longer-term developments in speed and range. B.108 Stage 2 would introduce a redesigned wing and reheated Gyron Junior D.GJ.12s.



Impression of the B.108. BAE Systems via RAFM

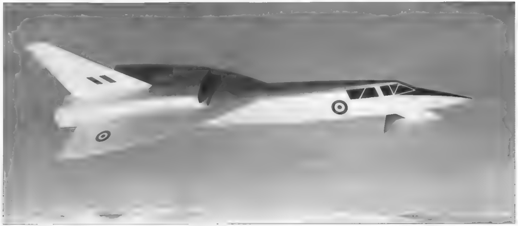
The B.108's D.GJ.4 Gyron Juniors were the same as the B.103's D.GJ.1s except for the addition of cooled turbine blades. These gave B.108 a top speed of Mach 0.95 at sea level though Mach 0.85 was felt sufficient for penetration at low level. Climb and cruise would be at Mach 0.85, dive at 748mph (1,204km/h) Mach 1.05. There was no supersonic capability since Blackburn felt the required service entry date effectively ruled this out. Supersonic performance would give an aeroplane 50% larger than a transonic machine with a much increased development time and cost. Several supersonic projects had been studied but it had been found that their general characteristics made them most unsatisfactory as high-explosive dive bombers and unsuitable as a limited war weapon. The first of four B.108 development aircraft (the 11th B.103 modified) would be ready to fly in January 1960.

Bristol 204

Bristol's 'Gothic' wing design was intended to have low bumpiness characteristics, meet the stringent take-off and landing limits without using direct lift and very high-blown flaps and have good supersonic performance without degrading its subsonic performance. Thus a relatively thick and lightly loaded (79lb/ft² [386kg/m²]) wing was chosen with simple trailing-edge flaps trimmed by a foreplane. Recent work had revealed that the Gothic's flow pattern was more stable than that of a conventional narrow delta, especially at high incidences, and induced drag was considerably lower than for a plain delta.

A 'Gothic' foreplane was mounted under the nose on a pylon, the front section having 10° upward movement and the rear 40° downward. This was to be used as the primary longitudinal control and to trim out the main wing's full-span single-slotted trailing-edge flaps/ailerons. Foreplane span was 8ft 5in (2.6m) and area 50ft² (4.7m²). The powerplant was integrated with the wing by putting the intake on top and burying the engines behind the combined frontal area of intake and wing. Bristol felt the resulting configuration should give good subsonic performance, be free from major handling vices and be inherently good from a fatigue point of view. No new basic aerodynamic information would be required other than that currently being produced for the supersonic transport programme, where much theoretical and experimental work was under way.

Type 204 used mainly conventional skin-stringer construction, primarily aluminium but with some titanium and stainless in the hot regions near the engines. These were Olympus 22s modified from the Ol.15R with simplified reheat to give 15% more thrust; Ol.15R had been found to be a better engine than the Rolls RB.141. Two were placed side-by-side at the rear with convergent-divergent



Above: **Bristol 204 model.**

Bristol Type 204 (14.1.58).

nozzles and an unusual 'letter box' two-shock wedge intake. Partially buried in the wing at the front, the engines broke through the bottom surface at the rear to form a complete nacelle. A central keel ran between the engines and through the intake while the nacelle's sides were carried forward as main ribs in the wing. The swept fin grew from the keel and had a conventional rudder. Four-wheel main gears were placed well outboard but retracted inwards into the wing adjacent to the fuselage.

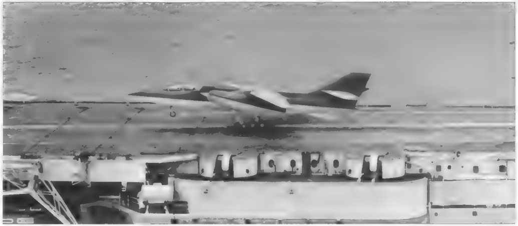
A mission radius of 875nm (1,621km) could be achieved on 4,334gal (19,706lit) of internal fuel but the specified 1,000nm required drop tanks under the wings, though in-flight refuelling could be utilised. The front part of the wing outboard of the body formed the forward main fuel tank, the aft main tank came behind the bomb cell under the wing. Radars comprised a forward-scanning 24in (61cm) X or J-band plus a sideways J-band navigational aerial and a photo reconnaissance pack was included. Red Beard or four 1,000lb (454kg) bombs were held in a mid-fuselage internal bay to be lowered beneath the fuselage prior to release. No programme dates were given but a Type 204 fighter was projected.

De Havilland Christchurch GOR.339

An unnumbered design from W A Tamblin's team at Christchurch which had a kinked 8° variable incidence wing with podded engines, the weight saving on such a wing having been proved on the American F8U Crusader fighter. A moderately high loading of 110lb/ft² (537kg/m²) was chosen, mainly for the low-altitude sortie to help crew comfort and structure fatigue. High-lift devices included plain blown flaps, drooping and blown ailerons and a full-span drooped leading edge. Tail and fin were conventional and a central undercarriage had a four-wheel main bogie with stabilisers under the engine pods.

The RB.142R was chosen from a selection of engines, its low specific consumption and high reheat thrust giving good flexibility. The engine nacelles had fixed centrebody intakes and continuously variable nozzles and were far enough away from the aircraft centreline to avoid undue heat and noise effects on the rear fuselage structure; provision was made to fit a 15,000lb (66.7kN) Spectre rocket if required. The wing incidence deflected the engines downwards providing a significant vertical thrust component relative to the fuselage and tail. With reheat, climb from 1,500ft (457m) to 50,000ft (15,240m) would take 1.4 minutes, accelerating to Mach 2 on the way. Then, allowing the speed to fall off, the climb could continue until over 80,000ft (24,384m) was reached in a total time of 2.5 minutes, before the aircraft fell back below its 1g ceiling of around 60,000ft (18,288m). Top speed with reheat unlit was Mach 1.04 at sea level, Mach 1.30 at 36,000ft (10,973m).

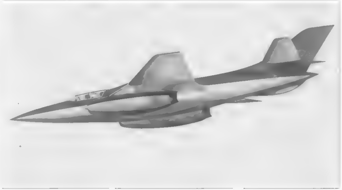
Sufficient internal fuel (3,750gal [17,051lit] in the wing and four fuselage tanks) was carried for the 600nm sortie but drop tanks, stressed for supersonic speed but jettisoned prior to the high-speed burst, were needed for 1,000nm. Studies suggested that an all-up-weight exceeding 70,000lb (31,752kg) was needed to carry enough internal fuel for the full mission but this smaller aeroplane met



most of GOR.339's limits. Flight refuelling was available in the 'buddy' installation that had proved successful on the Sea Vixen and Scimitar. DH felt the fuel reserves suggested in GOR.339 were unnecessarily stringent, studies with the Canberra and Javelin indicating that they could be some 25% less. If the 100nm (185km) penetration at Mach 2.0 was done at Mach 0.9 at low-level, radius of action rose by 120nm (222km).

The proposal had no forward-scanning radar (the nose could accommodate a 30in [76cm] dish), but sideways navigation and reconnaissance sets and photo reconnaissance equipment were fitted. Red Beard or two 1,000lb (454kg) bombs were housed internally and two more bombs were attached around the outside of the slightly protruding mid-fuselage weapon bay; for overload, two more were carried on underwing pylons. Rockets, extra fuel or a reconnaissance pack could also be installed in the bay. A VTO option involved a wraparound belly fairing containing eight rockets which allowed the aircraft to lift off from its own pad. DH stated that if contracts were placed in the autumn of 1958 it would be possible to have the type in service early in 1965. A brief examination had been made for operating this aeroplane from FAA carriers and as a fighter, the high available thrust giving fighter-type performance.

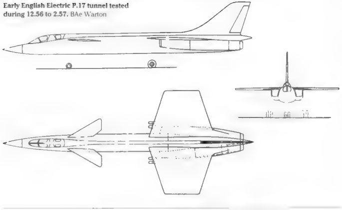
De Havilland GOR.339 (first drawn 23.12.57).

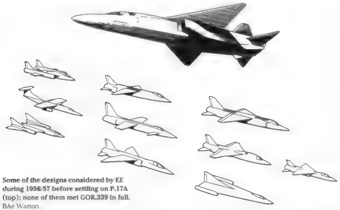


Above: **This model of a DH GOR.339, 'aboard' HMS *Ark Royal*, shows its variable incidence wing in operation.** BAE Systems

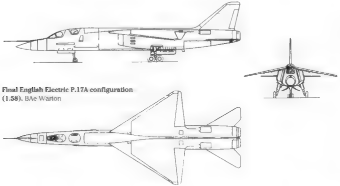
Right: **Impression of de Havilland's GOR.339 aircraft.** BAE Systems

Early English Electric P.17 tunnel tested during 12.56 to 2.57. BAe Warton





Some of the designs considered by EE during 1956/57 before settling on P.17A (top); none of them met GOR.339 in full. BAe Warton



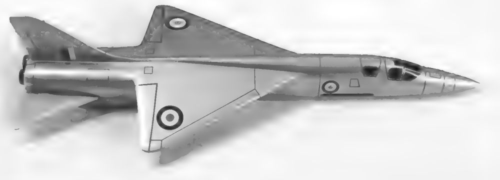
Final English Electric P.17A configuration (1.58). BAe Warton

English Electric P.17

EE's private venture studies for a 'Canberra replacement' began in mid-1956, well ahead of GOR.339, when it was necessary to guess the required performance. Discussions with the MoS began in October and a figure of Mach 1.3 in the target area was quoted, along with thoughts of a P.1B (Lightning) variant. This was taken up, EE's ideas becoming the P.17, the P.1B development the P.18. Through the winter a long series of projects were assessed under the P.17 label before, in January 1957, apparently settling on a straight equi-tapered wing, twin side-by-side RB.133s, intakes below the wing and a low-set tail. However, work continued on deltas and by October this planform's superiority was clear, the configuration was set and tunnel tests concentrated on refining it. P.18 was dropped once it was clear the type could not meet the RAF's range and airfield performance limits.

The favoured layout, a delta with a low-set all-moving tail and single fin, was called P.17A. At the time the P.1B was the only aircraft under operational development with high supersonic experience and an integrated weapon system, which was of great value to P.17A. Most important of all it was the only aircraft in the world known to have flown with good controllability up to Mach 1 at very low altitudes in very rough air. Hence some P.1B features were carried over into P.17A, particularly the low tail and leading-edge sweep. Favoured powerplant was the RB.142R though the aircraft could accommodate Olympus 14s or 15s with minor changes. Each engine had an individual shock-controlled intake, designed for efficient operation up to Mach 2.0, and variable nozzles of convergent type.

P.17A's structure was largely aluminium. The wing had full-span blown flaps with no ailerons, roll control being provided by differential movement of the tail. The whole trailing edge was hinged to form the blown plain flap which in normal flight was locked rigidly to the wing to prevent flutter. The wing's primary box structure was formed by top and bottom skins reinforced by conventional stringers; loading was 108lb/ft² (527kg/m²). A large mid-fuselage armament bay had a rotating door to allow photo reconnaissance or ground attack rocket packs to be quickly installed, while it easily accommodated the overload six 1,000lb (454kg) bombs. No weapons were carried under the wings. Electronics included a terrain-following attack radar derived from the intercept model AI.23, and sideways navigation and reconnaissance aerials. The tricycle undercarriage retracted into the fuselage where the majority of the



Model of P.17A made by Joe Cherrie.

internal fuel, 4,300gal (19,552lit), was also housed, sufficient for the 1,000nm (1,852km) mission.

Over a number of years, English Electric and Shorts had successfully collaborated on several programmes including certain marks of Canberra and the S.B.5 low-speed development aircraft for the P.1; in addition, Shorts had extensive VTOL experience. As a result, the brochure also detailed the P.17D lifting body which, rather confusingly, was labelled P.D.17 by Shorts. EE felt it was not possible to develop a VTOL type in time to fulfil GOR.339 so, instead, designed an aeroplane for use off conventional runways (P.17A), while Shorts added the separate piloted lifting VTOL platform (P.17D). This would act as a parent aircraft to take P.17A aloft vertically and then accelerate to its flying speed for release. It offered extra range or the advantage of surprise in making an attack from an unexpected direction.

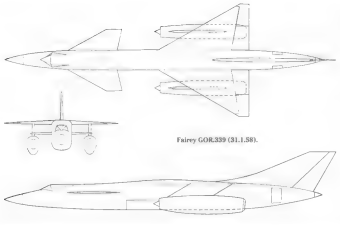
P.17D was a flying wing with tip extensions and fins at the tips. It used 56 Rolls RB.108 engines with two banks of 18 mounted vertically along each leading edge, two groups of six either side of the rearwards cockpit that could tilt to assist transition to and from forward flight, and another eight providing normal forward power. P.17A was attached by a large hook and together they totalled 128,000lb (58,061kg); P.17D weighed about 46,000lb (20,866kg). Procedure was to ascend vertically to 2,000ft (610m) in 40 seconds and then accelerate horizontally to 230mph (370km/h) before release. For retrieval the two would formate at 230mph and engage before returning to base and setting down vertically. (One wonders about the maintenance job and the noise this astonishing idea would have brought with it.)

A STOL P.17A called P.17B had been considered with three RB.108s for lift. Shorts designed the installation and twin RB.133s provided propulsion, but it was found that take-off distance was reduced only at the expense of either extra weight or less range. Other V/STOL jet lift proposals were labelled P.17C. Shorts had initially produced its own GOR.339 studies using STOL jet lift, the most promising having a 60° delta, 16 RB.108s and two RB.142s; all-up-weight totalled 100,000lb (54,360kg). When discussions with EE had started it was found that this basic layout was similar to the much more thoroughly developed P.17A, so several features were incorporated into Shorts' project. This became the P.17C with two RB.142s and 28 RB.108s in two banks of 12, one behind the cockpit, the other ahead of the fin; length was 101ft (30.8m), span 41ft 4in (12.6m), vertical take-off weight 83,300lb (45,282kg) and overload CTOL all-up-weight 110,900lb (60,285kg). Although this offered some marginal advantages over P.17A, it was later in timescale and introduced new problems when P.17A was already into detail design.

It was anticipated that the first relatively unequipped P.17A prototype would fly before the end of 1961 and ten development machines would be needed to get the type into service in late 1963. The composite system with P.17D would enter service in mid-1965, the first of the lifting platforms itself flying in late 1962. P.17A's combat performance was felt to be similar to current supersonic fighters so, again, a fighter derivative was proposed. As the P.22 this replaced the terrain radar with air intercept equipment and carried Red Top AAMs; P.17A itself was capable of development to speeds above Mach 2. In April 1958 Vickers approached EE about collaboration and copies of the P.17A and Vickers 571 brochures were exchanged. As a result, Shorts gradually disappeared from the scene.

Fairey GOR.339

The structural and aerodynamic features which contributed so much to the success of the Delta II research aircraft were again used here, the structure itself being based on Delta II's design and flight experience to cut down research and development time. Having rejected V/STOL, preliminary studies embraced twin and four-engine layouts using conventional, tailless and canard configurations with podded or buried engines. The smallest possible aircraft would be a tailless delta but its limitations included rocket boost for short take-offs. A conventional tailed layout was rejected because the best flight characteristics required a high wing and low tail. This made podded engines unacceptable as the jet efflux impinged on the tailplane and buried engines needed long intakes and pipes which increased weight. Hence, Fairey concluded that a canard 60° delta would best



Fairey GOR.339 (31.1.58).

meet the GOR, accepting that the foreplane might interfere with the intakes but giving many inherent advantages.

Foreplane span was 18ft 7in (5.6m) and area 228ft^2 (21.2m^2) and it gave an estimated 20% lift. Conventional light alloy construction was used, the choice for much of the structure being Hiduminium RR.58 because it was the best material for the flight temperature range. The wing had a loading of 92lb ft^2 (449kg m^2) which Fairey felt was sufficient to give acceptable conditions for the crew in low-altitude gusts. No form of auxiliary lift system (suction or blowing) was incorporated, bar reheat and methanol water, because of the problems created if an engine failed; this left just plain flaps and ailerons. A deck hook was fitted and a bicycle undercarriage was used with outriggers in the nacelles.

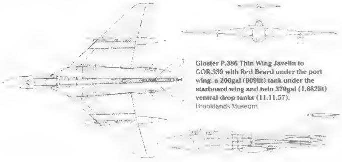
Overall length was rather more than that of an equivalent tailless delta so, for the lightest and simplest installation, podded engines were used which had simple cone centre-body intakes with no moving parts. The data covered two RB.142Rs with variable reheat but full interchangeability with the Olympus 15R was designed in for a slightly higher weight. Two engines gave adequate power for the various performance criteria, more would raise the ceiling but vastly increase weight. A very high sea level rate of climb with reheat lit added considerably to the type's escape potential and Fairey felt supersonic bursts should also be primarily looked on as a very temporary means of evasion or escape. In reheat, sea level rate of climb at 52,500lb (23,814kg) weight was 53,400ft min (16,276m min), at 62,500lb (28,350kg) this became 44,520ft min (13,570m min). Time to 30,000ft (9,144m) was 1.15 minutes and maximum sea level speed with reheat unlit was Mach 1.0. An analysis of supersonic flight at low level had revealed the rough exchange that every ten miles (19km) flown at supersonic speed cut overall radius of action by 55nm (102km). Consequently, Fairey excluded any supersonic elements from the operational profile.

Designed around the 600nm (1,111km) sortie, the airframe had a central fuselage bay to take either Red Beard, six 1,000lb (454kg) bombs or the rocket packs, the narrow span preventing carriage of underwing weapons. All the fuel, 3,600gal (16,369lit), was housed in fuselage and wing tanks and was sufficient to fly the 1,000nm (1,852km) mission. Electronics included an X-band forward-scanning radar and sideways-facing X-band navigation and Q-band reconnaissance equipment, while radar and photo reconnaissance packs, and a flight refuel pack, were available when needed. No details were given regarding development aircraft.

Gloster Thin Wing Javelin

Gloster conducted an investigation into GOR.339 but never tendered a brochure; however, a report dated 10th December 1957 summarised the study. It used the P.386 development of the Thin Wing Javelin fighter to F.153D as a basis which, with 4,500gal (20,461lit) of fuel (3,540gal [16,096lit] internal), could meet the 600nm (1,111km) radius of action but not the 1,000nm (1,852km) limit. Mach 2.0 level speed was also not possible; a best of Mach 1.13 was attained on the outward journey with Red Beard carried externally under the port wing, Mach 1.41 on the inward leg. To correct this and meet the GOR more closely, increased internal fuel and reduced supersonic drag were required.

More fuel space was found by taking the engines out of the fuselage and installing them in underwing pods. A fuselage redesign allowed carriage of stores internally which, along with the deletion of the external tanks, helped reduce supersonic and subsonic drag. Wing t c ratio was cut from 7.5% to 5% and area ruling applied. The resulting P.384 was faster but still could not reach Mach 2, Gloster noting that more power was needed which meant more engines. With 5,500gal (25,008lit) of internal fuel, P.384 reached the 600nm limit and with 7,000gal (31,828lit) the 1,000nm figure. Take-off wing loadings for P.384 with these fuel loads were 81.4lb/ft^2 (397kg/m^2) and 92.7lb/ft^2 (453kg/m^2) respectively.



Gloster P.386 Thin Wing Javelin to GOR.339 with Red Beard under the port wing, a 200gal (909lit) tank under the starboard wing and twin 370gal (1,682lit) ventral drop tanks (11.11.57). Brooklands Museum

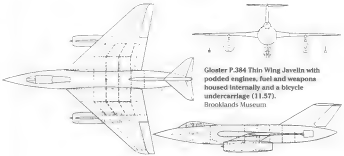
Handley Page Study

Handley Page did not tender but did produce an outline study using a rough working shape. This had a butterfly tail and a 4% t/c 'delta' wing with a rectangular centre section extending between two engine nacelles; span was 48ft (14.6m), length 75ft (22.9m) and wing area 924ft^2 (85.9m^2). No optimisation was attempted since the object was to find the effect of the GOR's requirements on size and all-up-weight, the report concluding that a 1,000nm (1,852km) radius might be possible with take-off weight at around 60,000lb (27,216kg) and no supersonic burst, provided high bypass ratio engines were used. Non-availability of such engines meant higher weight or less range and the low-altitude supersonic burst near the target resulted in a large take-off weight penalty. Top speed was about Mach 1.7 using twin RB.142Rs of 13,200lb (58.7kN) dry and 21,200lb (94.2kN) reheat. HP indicated no further interest in the requirement.

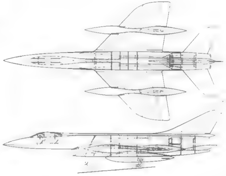
A further point was reflected in many GOR.339 brochures, i.e. a low-aspect ratio wing with high wing loading was needed in order to achieve an acceptable gust ride. The problem was that aircraft response to gusts in flight (of which there are many at low level over hilly terrain) increased with aspect ratio (ratio of span to average chord) and the inverse of wing loading (weight divided by wing area). Keeping the size and rate of the 'bumps' down at high speed and low level required a small, highly swept wing that would be somewhat inefficient in cruise. This led to a large fuel weight and a big fuselage and to enable the short wing to give short take-offs, auxiliary high-lift devices such as blown flaps were needed which were complex, expensive and added more weight. Weight escalation then became a factor. Today's fly-by-wire technology would have been a big help.

Hawker P.1129

Further developments of Hawker's P.1121 brought the P.1123 tactical bomber and P.1125 strike aircraft. The P.1123 was probably only a brief study but represented a final two-seat development of the chin intake P.1121 arrangement. It used a single reheated Conway 31R, carried the nuclear bomb semi-recessed in the lower fuselage, 3,310gal (15,050lit) of fuel and had four-wheel main gears. It also cured a weakness of the P.1121 in that the undercarriage and flaps clashed on the earlier aircraft where the flaps could not be lowered when the undercarriage was down; P.1123 remedied this by housing the main gears in 'Kuchemann type' fittings. The

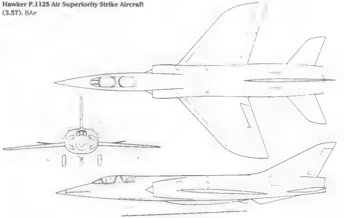


Gloster P.384 Thin Wing Javelin with podded engines, fuel and weapons housed internally and a bicycle undercarriage (11.57). Brooklands Museum

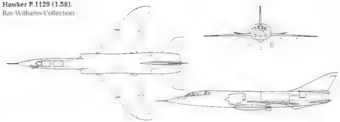


Hawker P.1123 Mach 2 Tactical Bomber (21.1.57). Brooklands Museum

Hawker P.1125 Air Superiority Strike Aircraft (3.57). BAe



Hawker P.1129 (1.58).
Ray Williams Collection



Two views of a model of the P.1129.

P.1123 was not a direct comparison to the P.1125, it was part of the process of development that had begun with the P.1103 fighter in 1954.

The P.1125 and P.1129 formed the main line of research and received more attention than P.1123. The single-seat P.1125 was the response to initial ideas for the forthcoming GOR.339 and used P.1121's outer wing panels and front fuselage. Internal fuel totalled 2,000gal (9,094lit), external 1,200gal (5,456lit), but the type was an exploratory step and was not tendered since the full GOR needed a bigger aircraft to accommodate a navigator. In fact the Hawker Design Department's preliminary studies to the full GOR, in October 1957, suggested that a large aircraft of some 130,000lb (58,968kg) weight was needed to meet the standard flight plan with supersonic burst. The Project Office then commenced investigating a 60,000lb (27,216kg) aircraft as a more likely compromise and P.1129 was the result. On 18th November Air Marshal Kyle, ACAS OR, visited Kingston where he expressed the opinion that the Air Staff would not be allowed to have a large aircraft; he thought P.1129 appeared a good compromise.

P.1129 was another project to use conventional light alloy construction. It had a take-off wing loading of 101lb ft^2 (493kg m^2) as a balance between a value to satisfy the performance criteria (including the loft bombing manoeuvre) and a desirable figure for crew comfort and structural fatigue during high-speed low-level operation. It was felt that the chosen value of 90lb ft^2 (439kg m^2) over the target provided tolerable conditions for the crew but it was acknowledged there was a general lack of practical evidence in this area and an active investigation would begin using a two-seat Hunter. This would include testing the effectiveness of spring-mounted seats to eliminate resonant frequencies which were known to be particularly distressing.

The airframe was considered to be the smallest possible to fulfil all the requirements. Full-span leading-edge droop and trailing-edge flaps with area suction were provided to augment lift for take-off and landing and the aircraft had a slab all-moving tail and a tricycle undercarriage retracting into the body. Over 40% of the fuel, 1,600gal (7,275lit), was carried in external tanks as overload and Red Beard was semi-recessed under the fuselage; alternatively, four 1,000lb (454kg) bombs could be mounted internally on rotatable Martin doors. Internal fuel in wing tanks and three large fuselage tanks totalled 2,250gal (10,231lit) and there was an optional tanker pack for in-flight refuelling

The 1,000nm (1,852km) radius could be achieved with the overload fuel.

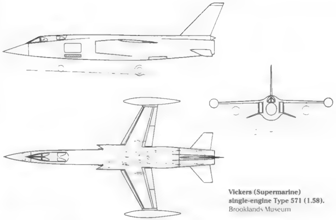
Electronics were kept to a minimum but P.1129 had a modified AI.23 with an 18in (45.7cm) dish for its forward-facing radar plus sideways X-band navigation and Q-band reconnaissance sets. The radar ranging and pilot attack sight doubled as a flying and navigation aid while specialised packs for all-weather reconnaissance were available as alternative loads to the bombs. Power came from two RB.142Rs which Hawker stated showed the best economy of any available engine; the Olympus 15R was a slightly less suitable alternative. The engines had individual intakes on the fuselage side with fixed two-shock half-cones, suction relief doors, and nozzles which were fully convergent-divergent. Absolute ceiling was at least 60,000ft (18,288m) and P.1129's small size bestowed fighter-type handling characteristics. Maximum speed with reheat unlit was Mach 1.05 at sea level, about Mach 1.2 at 36,000ft (10,973m).

The complete system could be in service in 1964 provided ITP arrived by July 1958. A programme for three prototypes, based on an April 1958 ITP, was:

First Prototype – first flight mid-1960. This would be used for aerodynamic and performance development with Olympus 14R or 15R engines since the RB.142 and parts of the weapon system would not be ready.

Second Prototype – first flight spring 1961. Used for engine and weapon development; this should receive RB.142 engines.

Third Prototype – first flight end 1961. This was to be as fully representative as possible to help prove the overall weapon system concept and the specialised weapon and reconnaissance packs.



Vickers (Supermarine) single-engine Type 571 (1.58).
Brooklands Museum

Impression of the single-engine Type 571.

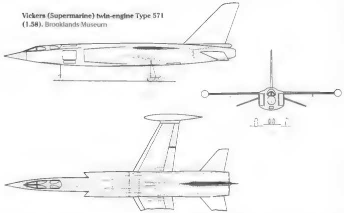
Vickers (Supermarine) Type 571

The Vickers military aircraft division had been formed from the previous Supermarine division with some reinforcement from Weybridge. Over 40 designs had been studied, six in detail, before two were chosen to form the tender. Variable geometry was rejected and early investigations showed meeting the GOR in one combined role would need a very large aeroplane. Thus, a policy of miniaturisation and alternative packs was adopted to keep all the military equipment to a minimum weight and size, which allowed the basic aircraft to be much smaller. Most of the brochure was devoted to a small single-engined layout favoured by Vickers but a larger twin-engined version was also described.

Type 571 had a light alloy structure though titanium was employed in the engine bay for load-carrying heat shields. Construction was conventional with frames, skins and stringers in the fuselage and skins with multiple webbing in the wing. Four ribs made up the complete wing box and the entire wing formed an integral fuel tank. More fuel was housed in the fuselage and provision was made for jettisonable tip and underwing tanks and flight refuelling. After studying those engines predicted to be available in 1964, it was concluded that the RB.142 would be the most satisfactory for these aeroplanes, although the Conway 11R/3C was considered. On the single-engine layout the RB.142 was placed right aft in the fuselage where noise would not damage the structure; both 571s had convergent-divergent nozzles and side intakes with raked-forward outer lips, an unusual feature in British designs.

Wing loading for the large 571 was 166lb/ft^2 (810kg/m^2); the smaller had the high figure of 194lb/ft^2 (947kg/m^2) which should solve the problem of severe turbulence frequency at low altitude. Compared to a Meteor flying at 460mph (741km/h), the small 571 showed a three-fold improvement in 0.5g gust response and a forty-fold improvement at 1.5g. An all-moving tail, all-moving fin and tricycle undercarriage folding into the fuselage were common to both proposals, the twin having tandem-wheel main gears. High-lift devices comprised full-span 'blown' drooped flaps. On the small machine compressor air was blown over the wing surface at the junctions of the nose and trailing flaps and the ailerons. This developed the system in use on the Scimitar and reduced approach speed by

Vickers (Supermarine) twin-engine Type 571 (1.58). Brooklands Museum



18mph (30km/h). A short take-off was possible using the 'Fire Hose' catapult system on the principle that it was better to have STOL apparatus on the ground than carry it around on every sortie. The large 571's extra power reduced take-off distance by 30%.

The design limit for both types was Mach 2.3 above 36,000ft (10,973m), the single-engine 571 being capable of Mach 2 up to 52,000ft (15,850m), the twin up to 54,000ft (16,459m). The small design could achieve the 600nm (1,111km) radius on 1,948gal (8,857lit) of internal fuel but needed small external tanks for the 1,000nm (1,852km) limit; the large machine could accomplish both on internal fuel. With four 375gal (1,705lit) drop tanks the twin's maximum weight reached 94,075lb (42,672kg). Common avionics included a 22in (55.9cm) forward-scanning X-band radar dish and sideways J-band navigation and reconnaissance radar aerials while identical weapon loads or alternative radar or photo reconnaissance packs were carried in mid-fuselage bays. Vickers felt the large version offered only marginal advantages which needed to be weighed against extra cost; therefore it was described in rather less detail.

From a start date of June 1958, the development programme outlined for the small 571 was first flight February 1962, first flight of a fully equipped aircraft February 1963 and CA Release May 1964. The required design effort was considered to be of similar magnitude to the Scimitar and the programme was based on this experience in addition to estimates for the Vanguard and VC-10 civil aircraft. Nine machines were planned for CA trials with two static test airframes; choosing the larger aircraft was expected to extend the later stages of the programme by about six months. Production would be at the company's South Marston Works. Vickers noted that should a single-engined aircraft be unsuitable, the small design could be fitted with two smaller engines for approximately the same performance and in February 1958 a brochure was prepared around this. In May a further brochure described a naval strike fighter variant suitable for carrier operations.

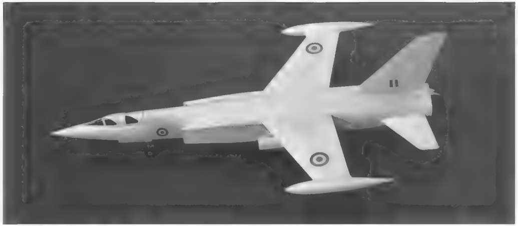
Choosing a winner from this long list of proposals involved rather more than assessing the designs although the best features of each were recorded in an effort to produce an 'ideal' configuration. Never before had such an advanced aircraft, so complex to develop and construct, been proposed for the RAF. Consequently, studies of each company's capability to produce, its experience in the supersonic field, manufacturing and flight test facilities, management strength and technical and scientific manpower, formed a major part of the assessment by the MoS, its Establishments and the Air Staff. For example, when reviewing structural aspects consideration was given to specialist experience, flutter, fatigue and kinetic heat testing facilities plus general experience of airworthiness and strength problems. Most weight was placed on the parent company, the supporting company (in parenthesis) being classed as subsidiary. The brochures were also taken as a measure of a company's ability to appreciate problems.

English Electric (partnered by Shorts and Vickers) was the most competent company from most aspects of structural design. Vickers-Armstrong (with EE) came next with the reservation that pressure of civil work might have an adverse effect on a GOR.339 aircraft. Avro's flutter team (as the focal point of Hawker Siddeley) was weaker but, apart from this, there was little to choose between the company and Vickers. Bristol (with Shorts) had a strong design team, especially on flutter and fatigue, with experience of high-speed research aircraft, but it was likely to take longer than the others to design the aircraft.

Of the rest, Fairey (Blackburn) was weak on flutter and vibration and general design. Blackburn (Fairey) would have been low on the list even without the Buccaneer, while the de Havilland proposal did not promote confidence in the design team at Christchurch which, it was felt, was unwise to rely on a support company with large civil commitments (the Airco agreement provided design assistance from Hunting and Fairey for the Hatfield division and its DH.121 civil aircraft, leaving a small contribution from Fairey for Christchurch's GOR.339). Flight test organisations were also closely scrutinised, those at EE, Avro and Vickers being first class with DH Hatfield not far behind from the evidence of Comet flight testing. But Christchurch, Blackburn, Bristol and Fairey were felt to be much poorer in quality. In fact de Havilland's Christchurch division fell far below the standards of Hatfield in many areas.

Regarding individual designs, Blackburn's B.108 was particularly disliked. An Air Staff memorandum dated 21st March 1958 described it as being much nearer to the original B.103 than the interim B.103A, thereby enlarging the deficiencies of that model. It was rejected because of inferior radar and too great a take-off distance that restricted the aircraft to V-bomber bases. Subsonic and with too short a range the conclusion was that B.103 and B.108 were no better than Canberra, except in speed, and it was unlikely that the RAF would ever require them. To purchase them as a replacement for Canberra would be unnecessary and outrageously expensive.

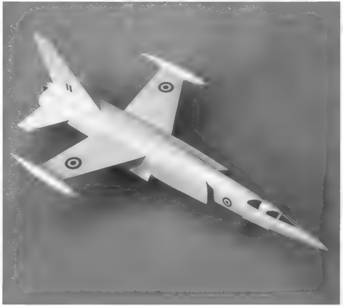
Unconventional solutions to GOR.339 were discussed, in particular variable sweep wings. EE had dismissed them because of mechanical problems whilst Avro felt that the necessary changes of sweep immediately before and after a loft bombing attack impaired the chances of success. It was significant however that Vickers, the company employing the leading advocate of variable sweep in Barnes Wallis, made no mention of it in its brochure, so the device was rejected by the assessment



group. VTOL was dismissed by many companies on grounds of increased development time and cost while self-contained VTOL reduced range. The EE Short lifting platform approach, however, had much to commend it since it only needed to be used in areas where VTOL was desirable; in other areas the bomber could operate from standard runways while, by itself, the platform could act as a freighter. The Assessment Group also concluded that a single RB.142 aircraft could not have GOR.339's radius of action unless it used runways that were 25% longer than specified.

It appeared the more promising aircraft to meet GOR.339 was a twin-engine type of conventional pattern. All of the companies had described such a type though Vickers put one as its second choice; the RB.142 was the most favoured engine. With the exception of EE and Vickers, the brochures presented contained little comment on the required instrument and electronic systems. It became clear that the choice lay between three groups. Hawker Siddeley, Vickers and English Electric. When GOR.339 was put out to tender, Hawker Siddeley's initial bid was not very powerful, but a subsequent revised and more promising technical approach was made coupled with detailed proposals for a combined design and industrial team (this revision is described in Chapter Eight).

Vickers' and English Electric's work was considered to be of the highest quality, not least through extensive preliminary studies which had given a marked lead over their rivals. EE's experience with the P.1 would directly benefit GOR.339 and a combination of these two teams would command excellent technical resources; EE's design team was considered particularly valuable. The possibility of awarding two design study contracts was discussed, one to Vickers and EE and another to Hawker Siddeley, but this was rejected because the latter was six to nine months behind and such a move would delay the programme by another year. Time was already short to achieve an in-service date of 1965. Hence, in July 1958 the Research and Development Board invited the Permanent Secretary to recommend that development of the GOR.339 system should be allocated to a combined Vickers and English Electric team with the former as leader.

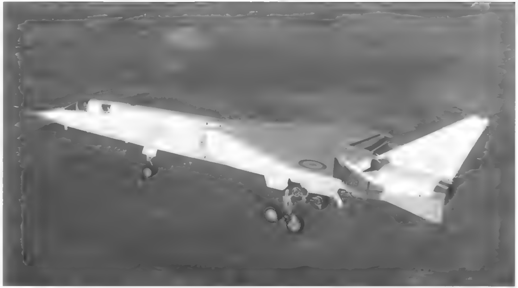


Above and right **John Hall's model of the twin-engine Type 571.**

Strike Aircraft Projects to GOR.339 – Estimated Data

Project	Span ft in (m)	Length ft in (m)	Wing Area ft² (m²)	t/c %	All-Up-Weight lb (kg)	Powerplant Thrust lb (kN)	Max Speed Height mph (km/h) ft (m)	Weapon Load lb (kg)
Avro 739	41 3 (12 6)	80 9 (24 6)	568 (52 8)	4 5 root	80 080 (36,324) 90,760 (41,169)	2 x RB 142R 'Medway' 14 590 (64 8), 23 620 (105 0) reheat	Mach 0 95 at sea level, Mach 2+ at 36,000 (10,973)	Red Beard 3 x 1 000 (454) 24 x 3in or 90 x 2in RPs internal 4 x 1 000 (454) under wings 2 x 37 x 2in RP pods on wing tips
Blackburn B.108	42 6 (13 0)	65 6 (20 0)	500 (46.5)	7 5	49 000 (22 226) (600nm only)	2 x D GJ 4 Gyron Junior 7,700 (34 2)	Mach 0 95 723 (1,164) at sea level	Red Beard 4 x 1,000 (454), 36 x 3in or 74 x 2in RPs internal 4 x 1 000 (454) external
Bristol 204	32 0 (9.8)	79 6 (24.2)	820 (76.3)	8.5	65,050 (29,507), 75,700 (34,338)	2 x Ol 22R Olympus 19,050 (84.7), 22 520 (100.1) reheat	Mach 0.95 at sea level, Mach 2 0 between 36,000 (10,973) and 55 000 (16,764)	Red Beard or 4 x 1,000 (454) internal 2 x 1,000 (454) 12 x 3in or 74 x 2in RPs under wings
de Havilland GOR.339	34 0 (10.4)	67 6 (20.6) without nose probe	440 (40 9)	5	48,750 (22,113), 60,400 (27,397)	2 x RB.142R 14,000 (62 2), 22,400 (99 6) reheat	Mach 1 3 at sea level, Mach 2 at altitude	Red Beard, 2 x 1 000 (454) 14 x 3in or 84 x 2in RPs internal, 2 x 1 000 (454) under fuselage 2 x 1,000, 12 x 3in or 74 x 2in RPs under wings
English Electric P.17A	35 0 (10.7)	84 6 (25 8)	610 (56 7)	4	66,000 (29,938), 73 400 (33,294)	2 x RB 142R 13,300 (59 1), 22,700 (100 9) reheat	Mach 0 95 at sea level, Mach 2 0 at altitude	Red Beard, 6 x 1,000 (454), 24 x 3in or 370 x 2in RPs internal
Fairey GOR.339	34 8 (10 6)	100 9 (30 7)	600 (55 8)	4	55,900 (25,356), 65,900 (29,892)	2 x RB 142R c14,000 (62 2), 22,700 (100 9) reheat	Mach 1 1+ at sea level, Mach 2 15 at 36,000 (10,973)	Red Beard, 6 x 1,000 (454), 12 x 3in or 74 x 2in RPs internal
Gloster P.386	60 8 (18 5)	72 0 (21 9)	1,235 (114.9)	7 5	83,050 (37,671) (750nm 1,389km radius only)	2 x Ol.21R Olympus 17,270 (76.8), 27,600 (122 7) reheat	Mach 0 95 at sea level, Mach 1 41 at altitude	Red Beard or High-Explosive bombs under wings
Gloster P.384	60 8 (18.5)	77 0 (23.5)	not given	5	100,500 (45,587), 114,500 (51,937)	2 x Ol 21R Olympus 17,270 (76 8), 27,600 (122 7) reheat	Mach 0 95 at sea level, Mach 1 58 at 36,000 (10,973)	Red Beard or High-Explosive bombs internal
Hawker P.1123	38 (11 6)	70 (21 3)	?	?	?	1 x Co 31R Conway	Mach 2 at altitude	1 x nuclear weapon
Hawker P.1125	38 8 (11 8)	67 0 (20 4)	510 (47 4)	?	?	2 x RB 133	Mach 2?	Nuclear weapon bombs, RPs, guns or guided missiles
Hawker P.1129	48 8 (14 8)	72 9 (22.2)	630 (58.6)	5	63,800 (28,940), 79,100 (35,880)	2 x RB.142R 13,800 (61 3), 22,500 (100.0) reheat	Mach 1 3 at sea level, Mach 2 3 above 36,000 (10,973)	4 x 1 000 (454) internal Red Beard, 4 x 1,000 (454) under wings, 48 x 3in or 222 x 2in RPs external
Vickers (Supermarine) Type 571 (Small)	28 0 (8 5)	58 0 (17.7)	200 (18.6)	5	36,820 (16,702), 45,400 (20,593)	1 x RB 142R c14,000 (62 2), 22,700 (100.9) reheat	Mach 1 1 835 (1,343) at sea level, Mach 2 1 1,388 (2,233) at 36,000 (10,973)	Red Beard, 4 x 1,000 (454) or 24 x 3in RPs internal; 4 x 1,000 (454) under wings
Vickers (Supermarine) Type 571 (Large)	41 6 (12.6)	77 0 (23.5)	430 (40 0)	5	81,225 (36,844) (full internal fuel), 88,300 (40,053) (1,200nm [2,222km] radius)	2 x RB 142R c14,000 (62.2), 22,700 (100 9) reheat	Mach 1 1 835 (1,343) at sea level, Mach 2 1 1,388 (2,233) at 36,000 (10,973)	Red Beard, 4 x 1,000 (454) or 24 x 3in RPs internal, 4 x 1,000 (454) under wings

TSR.2



The first TSR.2, XR219, seen on an early test flight from Boscombe Down with everything down. Note the wing leading edge without notches or saw-tooth and pronounced anhedral at the wing tips. North West Heritage Group

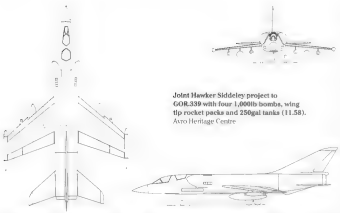
Politics in Extremis: 1958 to 1968

The submissions to GOR.339 show how designers could create many different shapes to the same requirement. They also reveal the great waste of effort generated by such severe competition within the industry of a small country like Britain, preparing and assessing so many designs to one requirement. Surely one of the better results of this story was the merging of most of the aircraft companies into two far more internationally competitive groups, Hawker Siddeley Aviation (HSA) and the British Aircraft Corporation (BAC), sad though it was to see so many famous names disappear. This step came into effect in February 1960 when the Blackburn group joined the other members of Hawker Siddeley (Avro, AWA, Gloster and Hawker) and Bristol, EE and Vickers joined forces as BAC.

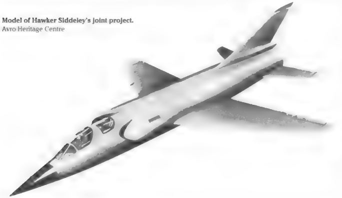
This chapter looks at the resulting aeroplane from GOR.339, the TSR.2, but first let us close Hawker Siddeley's part in the story. Chapter Seven noted that Hawker Siddeley's GOR.339 submissions came from Avro and Hawker (a covering letter stated that Avro's 739 was the main submission and represented the thinking of the group). Thin Wing Javelin studies were also made by Gloster and the three companies met regularly to examine their designs and consider joint development, but the Group as a whole was criticised for its confused submissions. One problem was that Avro, having lost the 730, considered GOR.339 as its natural field of interest and this resulted in some internal competition.

On 21st October 1957 the chief designers at Avro, Gloster and Hawker, J R Ewans, Richard Walker and Sydney Camm respectively, attended a Hawker Siddeley Group meeting, chaired by Sir Arnold Hall, to discuss GOR.339. On 13th November it was agreed that each company would submit its own proposals though by mid-December it was realised that Avro's 739 approached Hawker's P.1129 very closely indeed. Walker had visited Hawker Aircraft on 11th December where the Kingston design team told him that the Javelin configuration was very inappropriate to the GOR's concept, a move that effectively finished that project.

A Group meeting between Sir Frank Spriggs, Sir Roy Dobson and J R Ewans on 27th January 1958 revealed a certain reluctance to officially submit the P.1129 but clearance was given on the evening of the 31st. In late February, Ewans told Hawker that he was worried about the lack of co-operation within the Group which might affect its chances in the competition but on 19th March Morien



Joint Hawker Siddeley project to GOR.339 with four 1,000lb bombs, wing tip rocket packs and 250gal tanks (11.58).
Avro Heritage Centre



Model of Hawker Siddeley's joint project.
Avro Heritage Centre

Morgan, Deputy Director at RAE, reported that the P.1129 brochure had been well received at his Establishment. In late June Sir Arnold Hall was told that the P.1129 was second favourite to English Electric's P.17A.

The policy changed on 4th July with a move to resubmit a single Group project to OR.339 and Sir Sydney Camm was put in overall charge of the design team. Four days later it was agreed to use P.1129 as the basic design with certain improvements from the Avro 739. Joint investigations between Hawker and Avro were intended to produce an aircraft taking in the best features of the 739 whilst retaining the original P.1129 design features, in particular its small size, operational flexibility and relatively low cost. Brief details of this 'P.1129 Development' went to the MoS on 23rd July who agreed to give serious consideration to this 'promising design'. A full compromise design had evolved by 27th October 1958 which satisfied the main differences of opinion and a brochure was issued on 28th November by Avro under the heading of Hawker Siddeley Group.

Hawker Siddeley Supersonic Strike Aircraft

This unnumbered project closely resembled the July layout but had improved supersonic capability thanks to a reduced wing thickness, wing area and close attention to 'area-rule', to give minimum drag at Mach 1.34. It basically retained the wings, tail and fin of the P.1129 but had a redesigned fuselage. The P.1129's performance and effectiveness as a weapon system were improved and, without changing overall size, internal fuel was increased. The all-moving tail, with no dihedral, could now be used for supersonic speed roll control while the small, low-speed ailerons were placed further outboard than previously, which permitted larger-span flaps and reduced wing structure weight.

The 739 and P.1129 represented two approaches to the same problem and had differed mainly in size and wing load. On the P.1129 emphasis was given to airfield performance and subsonic cruise at altitude while the 739 was designed around the low-level and supersonic phases of the flight plan. Following the original submissions a series of intake configurations had been studied which resulted in a change from external to internal compression to give better thrust minus drag at supersonic speeds. Low-speed wind tunnel testing on the 739 had confirmed basic stability and control. RAE had tested a 739 radar echo model and its recommendations were also incorporated in this new project. Flap blowing was available on both leading and trailing edges.

Performance breakdowns were given for two RB.142/3 or Olympus B.Ol.22Rs for the standard 1,000nm sortie including 100nm (185km) at Mach 1.7; the respective all-up-weights for this mission were 73,700lb (33,430kg) and 74,850lb (33,952kg), take-off wing loadings 123 and 125lb/ft² (600 and 610kg/m²). Maximum speed was probably around Mach 2 (no figure was given) but the Olympus-powered aircraft had better supersonic performance. Internal fuel, carried in fuselage and wing tanks, totalled 3,536gal (16,078lit) which was sufficient for 1,000nm but two 250gal (1,137lit) underwing drop tanks increased flight plan radius to 1,200nm (2,224km).

Radar and reconnaissance equipment comprised a forward-looking modified Blue Parrot radar with a 28.3in (72cm) scanner in the nose and twin 7ft (2.1m) long sideways-looking X-band aerials mounted at the sides of the nosewheel bay. Further radar and photographic reconnaissance equipment included Q-band aerials, linescan and various cameras carried as a separate pack in the mid-fuselage weapon bay. The weapon bay had been redesigned so that two Bullpup guided missiles could be carried as an alternative load to either Red Beard, conventional bombs or rockets or a flight refuelling pack.

A development programme envisaged 34 months between ITP (assumed January 1959) and first flight, ITP covering mock-ups, test rigs and tunnel testing; a full weapon system contract would follow later in the year. Twelve development aircraft and two static test airframes were planned with the first four flight articles receiving minimum equipment. The next five would be partially equipped and the final three fully fitted and, after completion of development flying, would be delivered to the RAF. Initial CA release was estimated to be end 1963 with full release in mid-1964. The analogy with the combined English Electric and Vickers designs which produced TSR.2 is notable and the author considers this project to be the 'Cup Finalist' with that aircraft.

Hawker P.1121

Concurrently, Hawker continued studies to adapt the P.1121 into a two-seat all-weather strike reconnaissance aircraft as a cheaper alternative to GOR.339, completing a brochure on 1st July 1958. The design retained Mach 2 performance at high altitude but introduced ground attack strength factors and supersonic capability at sea level. Its Olympus 21R combined good supersonic performance and economical cruise consumption and both leading and trailing edges had flap blowing. Red Beard, two 1,000lb (454kg) bombs or a reconnaissance pack were carried partly recessed under the fuselage; four underwing pylons could each take a bomb, rocket battery or a drop tank. Overload weight (two 300gal [1,364lit] tanks inboard, two 200gal [909lit] outboard) was 54,590lb (24,762kg) and internal fuel totalled 1,500gal (6,820lit). The 600nm radius could be achieved but 1,000nm needed flight refuelling. Consideration of P.1121 in this role continued into October 1958.

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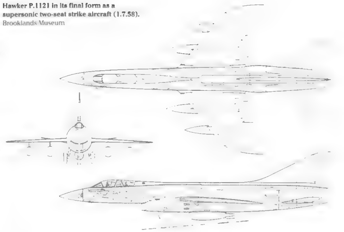
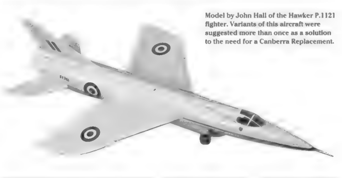
Vickers' single-engine 571 was considered very promising but in August 1958 the company looked at the merits of one or two engines and produced a 'condensed twin' proposal offering both airfield and speed performance. On 17th December a House of Commons statement noted that GOR.339 had been approved and design contracts were about to be issued. This was the first public acknowledgement of the project's existence and it became a hot topic with both the Press and MPs; much of the content of the draft OR was disclosed by Government officials with a surprising lack of reticence and security. Internally it was stressed that this was a different aircraft to the Avro 730 so the same excuses could not be used to stop it. On 1st January 1959 the Minister of Supply, Aubrey Jones, announced that Vickers-Armstrong and English Electric were to develop a new strike aircraft, for the first time called TSR.2, using the Olympus engine. Sir George Edwards of Vickers would head the project. This was also a deliberate move towards reorganising the aircraft industry.



Hawker P.1121 in its final form as a supersonic two-seat strike aircraft (1.7.58).
Brooklands Museum



Model by John Hall of the Hawker P.1121 fighter. Variants of this aircraft were suggested more than once as a solution to the need for a Canberra Replacement.

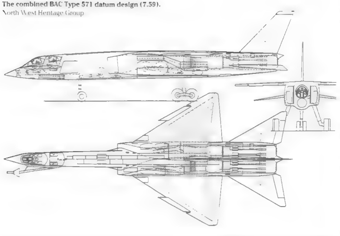
Air Chief Marshal Sir Claude Pelly, Controller Aircraft, told Sydney Camm on 8th January that the decision to use Vickers and EE had been made in the summer of 1958, which confirmed suspicions that Hawker Siddeley's later OR.339 work had been a waste of time (a Ministry document described it as a 'going through the motions' effort). Missing out on orders for its P.1129 type aeroplanes was a great disappointment to HSA and from now on Avro concentrated on civil types while Hawker moved on to the VTOL P.1127.

OR.343

A new, more advanced requirement, OR.343, replaced OR.339 in May. The original GOR had essentially been a 'feeler' or preliminary target designed to stimulate reaction from the MoS and industry; OR.343 was much more precise being written against the background of technical advice from these sources. In some areas it was more exacting, the more significant differences being: minimum height 200ft (61m) or less instead of 1,000ft (305m); Mach 2 at altitude, which would require some air intake development and the introduction of ECM; and operation from lower-grade airfield surfaces. Development costs to initial CA release were estimated to be £62m with first release for nuclear strike in December 1965.

TSR.2 was essentially moulded from the P.17 and Type 571, EE's wing and blown flaps, tail and rear fuselage being combined into a datum design with Vickers' long fuselage. EE's team was the only one to have extensive experience of Mach numbers up to 2 and it accordingly centred upon the aerodynamic,

The combined BAC Type 571 datum design (7.59).
North West Heritage Group



stability and control aspects of the design. Vickers had instituted a far-reaching study into electronic systems and airborne equipment and, in consequence, had a more refined fuselage in its Type 571. The aircraft split cleanly near the trailing edge of the wing box; Vickers was to make everything in front of this line, EE was responsible for the wing, rear fuselage, powerplant installation and tail. This arrangement satisfied the 50/50 split between the two companies and, for administration, the position was greatly simplified by the formation of BAC. The engine would be developed by Bristol Siddeley Engines (BSE), formed by merging Bristol and Armstrong Siddeley. During 1959 the Netherlands and Australia showed strong interest in the aircraft.

Vickers-English Electric Type 571

A Preliminary Brochure describing the agreed datum design was produced in late July 1959. It was still known as the Type 571 and a growth of 12.5% on dry weight had been made to cover the additional performance requested in OR.343. P.17's delta wing was picked ahead of Vickers' swept wing because it offered better gust response and transonic handling characteristics, though both were suitable aerodynamically. Revised data had been received for the Olympus 22R which, compared to the de Havilland PS.53/3, adversely affected the range and take-off distance, giving values which at this stage were unsatisfactory. To restore the performance, wing area had been increased by 10% with a consequent increase in the size and weight of the whole aircraft.

Using blown flaps increased lift at low airspeeds quite dramatically; high-pressure high-temperature air was bled from the engine compressors and piped to the wing trailing edge where it was blown over the extended flaps to re-energise the 'tired' airflow. Without blowing, the upper surface airflow over both wing and flaps could begin to break up and become turbulent at low airspeeds, leading to a loss of lift and more drag. Selecting blowing kept the airflow in contact with the upper surfaces and prevented it from breaking away, thus increasing lift. The aircraft had an all-moving fin, all-moving tail with part-span trailing-edge flaps, a notched leading edge and a sawtooth and, at this stage, square intakes (variable half-cone intakes were adopted in 1960).

In December 1959 the MoA sought Treasury approval for a full development contract to initial CA release, but only limited approval was given while the whole matter was reviewed, including an assessment of the Buccaneer whose 'inadequacies' were once again stressed. Three months later the Minister of Defence, Harold Watkinson, asked the Chiefs of Staff to advise him on the necessity of TSR.2 and a full study was set in motion. A cockpit mock-up was officially viewed at Weybridge on 14th January and in May the Minister asked for a study to give TSR.2 a strategic capability carrying a stand-off missile such as Blue Steel. The work included assessing the effectiveness of nuclear and high-explosive warheads against representative targets and the aiming accuracy that would be required with this aircraft to meet those levels of effectiveness. The need for TSR.2 was agreed on 29th July, but a month later Prime Minister Harold Macmillan reopened the whole issue and another assessment followed.

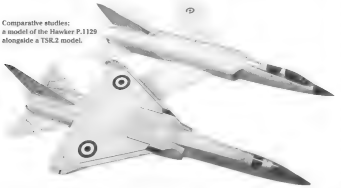
On 11th September 1960 Sir Solly Zuckerman, Chief Scientific Advisor to the Minister of Defence, compared TSR.2 against the Buccaneer and noted that 'there can be no doubt that the TSR.2 specification is up to the performance demanded of the aircraft and that there is no other that can meet it. The very best technical brains have bent themselves on this issue.' TSR.2 was expected in service as a strike aircraft in 1966 but it would not be perfected as a blind, all-weather reconnaissance aircraft, able to follow contours at 200ft (61m), until about two years later. However, Zuckerman had learnt that TSR.2's capacity to fly very fast and low, thereby exploiting a height range in which current defence systems could not operate, did not give it special merit in terms of vulnerability. The MoA and his own staff informed him that a speed of Mach 1.1 or 1.2 at low level gave no advantage over a speed of Mach 0.9. Even the Buccaneer, which could achieve the latter, would be to all intents and purposes invulnerable at low level unless the target had a standing supersonic fighter patrol. But TSR.2 would give a better ride and when the 'black boxes' were ready it would be a much better contour follower.

TSR.2's ability to fly at Mach 2 at height was acknowledged, but this might not mean so much by the 1970s when Soviet SAGW defences would have improved, although such speed would be a major advantage in any other theatre of operations. Buccaneer could not go supersonic but Brough's B.112 development would put the latter's speed at altitude up to Mach 1.6. TSR.2's size was also important – Buccaneer could not house the sideways-looking radar which was essential for critically accurate navigation. Zuckerman appears to have favoured both aircraft but he noted that if the OR was relaxed, which he felt was a valid point, then the RAF's needs could be met by an improved Buccaneer, which would save a lot of money.

Four days later Watkinson confirmed and supported the need for TSR.2. 'The whole history of air warfare had conclusively shown that performance was absolutely vital; only an aircraft with the requirements stated for TSR.2 could hope to survive and to fulfil its functions in the period under discussion, namely the late 1960s to the end of the 1970s.' There was no possible compromise, the Buccaneer could not be developed to approach the OR and the specified limits could not be reduced. As a result a full contract was placed in October 1960 for nine development aircraft with a first flight in March 1963.

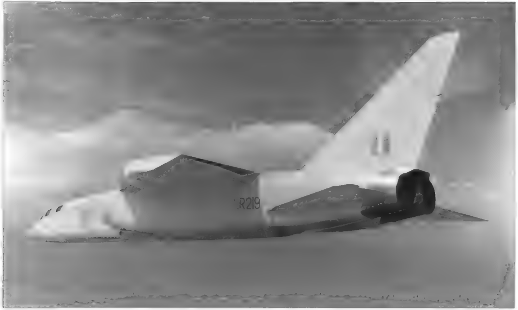
However, from the moment Watkinson raised the issue of a strategic nuclear role, TSR.2's performance requirements were gradually expanded (instead of simplifying the aircraft's systems to keep down the cost) and in 1961 the conventional and tactical nuclear load was increased, the latter being doubled to two bombs. In April 1959 Republic Aviation of America approached the Parliamentary Secretary with a view to influence the UK to order its F-105 Thunderchief as the RAF's strike and reconnaissance aircraft. In fact the F-105 had been considered in 1958 but it did not meet any RAF requirement and particularly OR.339 as it then was. The outcome was the passing of information to Republic on the Olympus, Conway and large de Havilland Gyron engines to assess their use in the F-105. This contact also established that the USAF had no light bomber of its own and the British Government considered it might be interested in TSR.2. Instead the F-111 was created to become a lethal rival.

Specification RB.192D, written around OR.343, was issued in August 1960. Instead of Red Beard, a tactical nuclear 'lay-down' weapon for low-level use was now planned to ASR.1177; this was to become the WE.177 which joined the RAF's inventory in 1966 and stayed until 1998. OR.343 Issue 2 was



Comparative studies; a model of the Hawker P.1129 alongside a TSR.2 model.

Second prototype TSR.2, XR220, under construction. This aeroplane never flew.
Eric Morgan Collection



accepted in May 1961; it introduced a performance ceiling of 56,000ft (17,069m) and increased to six the number of 1,000lb (454kg) HE bombs carried internally. Internal carriage of rockets and air-to-surface guided weapons was deleted and these changes were considered practicable without significantly increasing cost.

BAC felt the airframe would not present any problems and BSE was satisfied that the powerplant would meet the timescale. It was thought that the nav/attack system, a new area in electronics, would be the weak link. TSR.2 would have a comprehensive electronics suite, much of which broke new ground, and delays in developing such advanced equipment were thought to be inevitable. As it happened the airframe took longer to design and construct than was originally expected and the engine suffered a sequence of mechanical faults. By June 1961 progress was about three months behind schedule and two months later all-up-weight had risen to 93,283lb (42,313kg).

By now, powerful forces were lobbying against the project. One group believed that most of TSR.2's tasks could be performed by a ground-to-ground missile such as Blue Water while another saw no reason why the RAF's needs could not be met by the Buccaneer. Politicians were naturally concerned about the programme's eventual cost and to the Government in general it was hard to disguise the fact that a new aircraft meant a complete reversal to the policy that was stated in April 1957: 'The Government has decided not to go on with the development of a supersonic manned bomber' (the Avro 730).

Other problems were the often less than cordial relationship between Vickers and EE and the co-ordination between the many companies across the country, contracted or subcontracted into the programme, via a large committee system. In practice this impeded rather than helped the process of making decisions. In early summer 1962 the Ministry met George Edwards to consider cancelling the project because of its cost, but Edwards commented that this would make 1,100 design staff redundant and 'shake the industry to its roots'. It was agreed, however, that the cost estimates should be reduced and a great deal of effort was put into this, unfortunately without success because a further increase in BAC's estimate followed within six months.

On 11th January 1963 the Ministry told Edwards of its dissatisfaction over BAC's programme management which he acknowledged as a 'substantial failure'. Apart from increased labour and material costs, BAC

This later view shows the size of the all-moving fin and how 'clean' TSR.2 was when the undercarriage was retracted. Eric Morgan Collection

admitted that it had failed to make valid estimates of the effort necessary to complete TSR.2's development and to exercise sufficient control over its sub-contractors. Analysis showed that the failure not only applied to those parts of the project which broke new ground (mainly the systems), but also those which were of advanced but conventional design (such as the airframe) where BAC's experience should have stood it in good stead. BSE was also criticised for its method of estimating and financial control.

Two severe in-house critics of TSR.2 were Admiral of the Fleet Lord Mountbatten, Chief of the Defence Staff, and now Solly Zuckerman; both favoured the Buccaneer. The hostility to the project by Harold Wilson's Labour Opposition Party, prior to taking office as the new Government in 1965, is also well documented. But from 1962 serious doubts also existed within the Conservative Government. In late January 1963 Macmillan asked how the project was progressing and for details of cost estimates. Julian Amery, Minister of Aviation, replied that the estimated cost for R&D had risen from £90m in December 1959 and £137m in March 1962 to a present £175m minimum, £3.5m representing 'improvements resulting from changes since the programme was approved (e.g. modifications asked for by the Air Ministry)'. Taking away increases in wages and material costs, the net or true increase was at least £65m.

Amery thought this was 'very serious' and put it down to two reasons:

i. The firms and the Ministry greatly underestimated the difficulty of the job and hence the time it would take. We were, of course, attempting something quite new and there was little or no past experience to guide us. In a project of this kind, delay in R&D involves a direct and steep increase in cost. It is the men's time and the daily overheads of the firm that are expensive.

ii. Until very recently management control of the airframe was in practice split between Vickers and English Electric.'

As a result, work at both factories had been brought under unified control with a single man responsible. Amery had no doubt about the project's technical validity but there were clear worries. (Watkinson has written by hand on this document 'Minister: This is a terrible story. I suppose we are prisoners to our decisions. When will all this come out?')

One factor behind TSR.2's high cost compared to previous projects was the use of more expensive materials such as titanium alloys, high-grade steels and aluminium-lithium alloy sheet. In mid-February the Defence Research Policy Committee (DRPC) approved continuation of the project but with much reservation, criticism and suggestion for economies. On the 7th, ACAS(OR), Air Vice-Marshal C H Hartley, questioned 'the competence of the MoA...either to manage a major project or to offer any valid advice about it'; there was plenty of dispute between the Ministries.

TSR.2 could not fulfil a full strategic role because it lacked the V-Force's range yet the aircraft was considered as such to fill the gap between the V-bombers and the Polaris deterrent bought by Macmillan in 1963 after Skybolt was abandoned. Polaris was a submarine-launched ballistic missile and its acquisition brought the momentous decision to transfer the responsibility for the British nuclear deterrent from the RAF to the RN. The transfer was made on 30th June 1969.

On 15th November 1963 Alec Douglas-Home, Macmillan's replacement, minuted his Minister of Defence Peter Thorneycroft: 'I am rather troubled about this project. It seems to be turning out to be considerably more expensive than we thought; and its military value is also being called into question. Ought we to have a new look at the whole venture and satisfy ourselves that it is still an integral element in our defence programme'. The reply noted: 'Unless we find a replacement for the Canberra of a quality which will enable it to live in a hostile environment of the sophistication which will be inevitable in the 1970s, we will cease to be an effective air power. By 1968 the Canberra will be worn out and in any event could not survive even against second class opposition. Our ability to hit targets behind the immediate battle area will have gone'. This conclusion was reinforced by the 'very serious fall-off that will occur in our conventional air capability with the phasing out of the V-Force in the early 1970s'.

By March 1963 the first flight was now due in January 1964; by April 1964 this had slipped to mid-1964 due to some engine failures during bench testing. Beyond nine development and eleven pre-production machines (the latter approved in June 1963) a total of

TSR.2's characteristic wing tip vortices seen just after XR219 had taken-off. North West Heritage Group

A sad sight - one of the incomplete TSR.2s being chopped up at Warton in 1965.
North West Heritage Group

138 TSR.2s were planned for the RAF with production to be complete in 1973; there were suggestions for 320. Aircraft 1 to 9 were for development, 10 to 14 would go to A&AEE Boscombe Down and 15 to 20 were earmarked for the RAF's TSR.2 Development Squadron (237 OCU) at Coningsby. The Air Staff wanted the nuclear strike role to get first priority and CA Release to clear the 21st aircraft to drop a nuclear weapon by single means was expected in January 1967. Material for 30 production TSR.2s was ordered in March 1964.

On 21st August 1963 it was decided to finally drop the 2,000lb (907kg) Red Beard nuclear store because of the difficulties in carrying it plus the confidence that the new WE.177 would be ready within TSR.2's timescale. TSR.2 would now carry two versions of WE.177 (Types A and B), 1,000lb (454kg) HE bombs, 1,000lb retarded HE bombs to AST.1194, 2in (5.1cm) rockets, both versions of a new air-to-surface tactical missile to ASR.1168 and bomblet dispensers to AST.1197. The salient features of TSR.2 were released to the national press on 28th October. A month later the Germans showed some interest in the aircraft as a replacement for the F-104G; possibly 400 aircraft might be needed. Federal Minister of Defence Herr von Hassel and his party saw the prototype at Weybridge in May 1964 but there were concerns in the British Cabinet about repercussions in the UK if the Germans were allowed to buy an aircraft capable of delivering nuclear bombs, despite the fact they were still under United States custodial arrangements.

A big blow was Australia's decision in October 1963 to buy the American TFX (which became the F-111) instead of TSR.2. On the 30th, G McD Wilks noted that 'Australia's choice of TFX abandoned their usual insistence for a proven aircraft and they have chosen an aircraft much further away from service than TSR.2. [Robert] Menzies stated that the RAAF *did* recommend a proven aircraft (the American RA-5C Vigilante) and that it was the Australian Cabinet which, for financial reasons, selected the TFX out of the two unproved aircraft. Their Canberras are wearing out quickly and the Australians could undoubtedly get TSR.2 more quickly into service...I think [the] Australians have basically taken a political decision'. TFX (F-111) was now a very serious rival to TSR.2 although the Ministry felt its planned in-service date of 1967 was 'decidedly optimistic'. It was known that General Dynamics, TFX's manufacturer, was having problems and sections of the USAF's Headquarters were impressed by the way Vickers had overcome some of its difficulties. The feeling was that Vickers was doing a better job in certain areas than General Dynamics.

But costs still rose. TSR.2 was the only combat aircraft for eight years to undergo a full-scale development in Britain and so it carried the burden of supporting the basic R&D which would be required for any advanced national aviation programme. Hence the Air Staff felt justified in ensuring that it was capable of many different tasks, an essential feature in modern strategy. The resultant aircraft, though complex and heavy, could, according to the Air Staff, be applied effectively to any of Britain's many defence commitments. F-111 did not have nearly such a diverse operational capability. However, between 1963 and 1965 there were proposals for economy, such as deleting particular roles and equipment, but only small savings could be achieved and then only by disproportionate losses in capability. For example, it was concluded in 1964 that if the top speed was reduced from Mach 2.05 to 1.7, the saving in R&D expenditure would be only £3m.

The first aircraft, XR219, made a successful first flight on 27th September 1964. The wait had been a particular worry and on the 28th Geoffrey Tuttle told Amery 'It is a great weight off everyone's mind and I am encouraged to hear how satisfied Beamont [the pilot] was with the aircraft on the trip'. The next month the General Election returned a Labour Government and numerous comparisons immediately began between TSR.2, the American Phantom and F-111, a new Mk.2* Buccaneer and the Hawker P.1154 supersonic VTOL aircraft (Chapter Ten). Their cost, together with future defence strategy, was analysed closely to see if they were affordable and justified; Polaris was retained.

A report published in November by the Treasury noted that Britain had a relatively small defence industry and armed forces compared to America's much greater resources, plus a faltering economy, and so it could not afford to develop a wide range of weaponry. In recent years many projects had been cancelled by the Conservatives, while estimates suggested that the huge amounts of money invested in defence R&D produced just 2.5% of British exports. Many experts felt that obtaining American weaponry would be a good move; and many Members of Parliament and journalists in the media felt TSR.2 was over-ambitious.

Between 13th and 19th December a team led by Air Marshal Sir Christopher Hartley visited Washington and Fort Worth on a fact-finding mission for the F-111 (the first prototype had flown on 21st December), the F-4C Phantom and some transport aircraft. Around this time the Air Ministry moved in favour of replacing TSR.2 with the F-111, though it was still against the Buccaneer, and on 7th January 1965 strong rumours in the national press were forecasting TSR.2's cancellation. Eight days later aircraft industry chiefs and the Aviation Minister (Roy Jenkins) dined with Prime Minister Harold Wilson to discuss the future shape of the industry. On 2nd February Wilson announced cancellation of the Hawker P.1154 but he deferred a decision on TSR.2, principally to allow further studies to be made regarding the industrial and social consequences of cancellation.

By now the debate surrounding TSR.2 in Whitehall and the media was very bitter. By February 1965 the estimates had risen to between £252m and £272m for R&D, £55m for the eleven pre-production aeroplanes and £410m for a quoted production run of 147 aircraft. CA release for the nuclear role was now fourth quarter of 1967, for other roles it was fourth quarter 1968. Another MoD/MoA party visited America in March 1965 to learn more about F-111 avionics and on the 19th the Air Staff issued a paper which identified the requirement for either TSR.2 or F-111 while laying the Buccaneer Mk.2* and the F-4C Phantom to rest.

Amidst this mess the TSR.2's superb flying and engineering qualities were reported by Wg Cdr Beamont and in mid-March 1965 he completed a full appraisal of its handling characteristics which was sent to Jenkins. George Edwards added: 'In my 30 years of designing and making aeroplanes I have learnt that by one means or another, they can all be made to work. Every now and again the basic design conditions are met, or exceeded, right through the whole aeroplane. When this happens (and my only previous experience of this was with the [civil] Viscount) then there is very little alteration from the prototype to the production aircraft. All the available evidence points to this being the case with TSR.2'. However, the end was close.

The Cabinet decided to cancel TSR.2 on the evening of 1st April 1965 after two long meetings held during the day; this was to be announced on 6th April during that year's Budget speech. Denis Healey had pressed hard to replace the aircraft with the F-111 but others, including Jenkins, favoured cancellation without taking an option on the American aircraft. The discussions were heated and Straw and Young (see Bibliography) report that Wilson eventually presented the Cabinet with three alternatives: 'postpone a decision on TSR.2 even longer, cancel the aircraft without an F-111 option, or cancel and take the American offer' (the F-111 had been offered at very favourable terms). A 'substantial minority of about 10 ministers (against 12) argued for TSR.2's retention' on the grounds that if we eventually needed a bomber of this type, 'we would be forced to buy the F-111 and thus become unduly dependent on the United States'. In the end Healey's proposal was accepted but this in-depth article shows the decision was taken neither hastily nor easily. Work now began on a collaborative project with France called the Anglo-French Variable Geometry Aircraft (AFVG, see Chapter 14).

Cancellation was a huge step to take and brought both praise and criticism. Controller Aircraft (now Morien Morgan) was aghast at the implications of the 'surgical excision – rapid and complete – of the TSR.2'. He described the machine as 'the spearhead of advanced technology in this country. With its complex weapon system...it is the big spur to progress. Retaining our position as a force in the World aeronautical design scene means that we must undertake really advanced work – pedestrian projects would lead to steady decay'. On 7th April he sent George Edwards a telegram: 'Regret no further flying of TSR.2 is to take place. In the meantime both aircraft should be kept serviceable'.

On the 25th a survey began to examine the possibility for utilising the existing TSR.2s for research. It would be necessary to extend the flight envelope before any serious work could be done on an engine programme and this would need some 50 hours flying. Then a full programme could use two or three aircraft for 150 hours flying until the end of 1967 at a cost of £2-3m. This was expected to benefit the development of the Concorde SST's version of Olympus and areas analysed would include subsonic and supersonic engine handling and behaviour, intake configuration and effects, engine performance in subsonic and supersonic conditions, kinetic heating (TSR.2's long endurance would enable more data to be collected than would be possible with any other research aircraft), extending the flight envelope to Mach 2.05 between 40,000ft and 55,000ft (12,192m to 16,764m), aerodynamic stability at high Mach numbers, flutter characteristics and supersonic drag.

Controller Aircraft noted that the results would benefit the whole of our future aircraft programme, including Concorde and AFVG. But the Defence and Overseas Policy Committee decided on 1st June against further flights, noting that the money it required could be substantially more if any minor snags held up the flying programme 'which are almost inevitable on an aircraft of this performance and capability'. The flying so far completed by TSR.2 was achieved only by the immense efforts of a large and enthusiastic team. Jenkins advised that the risks of failure were 'very high. Spending £2-3m to get some return for an investment approaching £200m may at first seem an attractive proposition, but the information may not be indispensable'. James Callaghan, Chancellor of the Exchequer, felt it could prove to be 'a very costly business indeed. To embark upon such a programme would seem to run directly counter to the decision to cut our losses on this project and to release resources for more productive use.' He felt it was not worth contemplating such a programme.

So that was the end and the subsequent destruction of most TSR.2 hardware, with great haste, was considered in industrial circles to be totally unforgivable. Only the first prototype ever flew but the second was ready to fly, several more were nearly complete and manufacture had reached a point where components for many more airframes had been made. The author's former employer, High Duty Alloys Ltd, forged many different parts in aluminium, titanium and steel; each required planning, metal production, forging, heat-treatment, machining and testing. One large component, the 'tailplane frame', involved hand forging and machining a huge slab of RR.58 aluminium alloy into a fuselage rib to fit around the engines. It was 119in (302cm) wide, 46in (117cm) tall and over 9in (23cm) thick, and there would be one example per airframe. At cancellation 65 had been made only to become so much scrap metal. Most aircraft cancellations bring plenty of waste but much of TSR.2's technology did find its way into Tornado (see Chapter 14).

Artist's impression of the F-111K equipped with 600gal (2,728lit) wing tanks and 1,000lb (454kg) bombs. General Dynamics via Joe Cherrie

General Dynamics F-111K

To replace the TSR.2 the Government went for the F-111K, the designation for the British version of the aircraft, and through the summer of 1965 ASR.343 was drafted around it. In February 1966 the Defence White Paper established a need for 50 F-111s while rejecting a developed version of the Buccaneer Mk.2 and on 22nd March the UK signed the Letter of Offer for the first ten aircraft. In September the avionics and all major areas of the British F-111 configuration were fixed and a Preliminary Design Review, attended by a Ministry team, was held in the USA on 6th November. Basically the F-111K was a standard American F-111A given a higher gross weight take-off capability, some updated systems, some specific British systems and the capacity to carry British weapons. Two versions were to be delivered, a Strike Reconnaissance variant and a Trainer Strike type, and structurally their airframes were to be near identical. Each of the two prototypes would be configured to one form, No 1 acting as the Strike/Recce prototype and 'wired' to carry and launch the Martel ASM.

The option for the remaining 40 aircraft was exercised on 29th March 1967 and the first F-111K entered final assembly on 18th September. However, revised estimates received from America in early October 1967 indicated a significant degradation in the aircraft's strike radius and altitude performance and then on 25th November, as a result of a devaluation of the Pound, it was announced that the unit cost of F-111K had risen to £3.02 million. On 16th January 1968 the F-111K was cancelled, ASR.343 being held in abeyance from the 31st. During May 1969 it was decided to dismantle the two part-built F-111Ks for spares and this process was completed by the end of September.

In 1967 the Government, faced with a major economic crisis, abandoned Britain's commitment 'East of Suez', a move which rendered one of the main roles envisaged for TSR.2 as no longer necessary. Hence, F-111K followed it down the cancellation road to be replaced by the loathed Buccaneer, discussions beginning almost immediately regarding the type's existing capability and the modifications needed for RAF service. Former FAA Buccaneers began transferring to the RAF in 1969. The Air Staff did not rate the Buccaneer but it had, over the years, assessed the type perhaps more than any other aeroplane. Its opinion was backed by some of Britain's allies and on 12th April 1965 the *Daily Telegraph* quoted one US General commenting 'If the RAF operates the Buccaneer in the 1970s it will give its opponents the hysterics and earn the pity of its friends. The US Air Force discarded aircraft of the Buccaneer's performance a decade ago'.

Dassault/BAC Mirage IV

In 1965 a French Mirage IV fitted with Rolls-Royce Speys rather than the usual SNECMA Atar 09K jets was proposed as a substitute for the F-111K, and in July an MoD/MoA team visited Dassault to evaluate the concept. A detailed joint study by BAC and Dassault, completed in November, postulated that a significant improvement in range was achievable using the Spey's better fuel consumption. Modifications necessary to accommodate the Spey would include a longer fuselage (which permitted extra internal fuel), redesign to the majority of the rear fuselage and larger intake ducts, but there were no major structural changes. However, Mirage IV only offered an 870nm (1,611km) range rather than ASR.343's 1,000nm (1,852km) and, having been specifically designed for high-altitude nuclear strike, fitting British equipment for long-range strike recce operations could make it as expensive as F-111K. Some members of the Air Staff felt that the French were really chasing a British rejection of the F-111 – the French would not object to the RAF buying the Buccaneer rather than the Mirage IV, but it was well into 1966 before the idea was officially rejected.

Such is the controversy surrounding TSR.2 that one feels expected to criticise and blame someone for its cancellation, but I cannot do that. The aircraft seems to be the unfortunate victim of the coming together of a series of adverse circumstances, each of which alone might have been solved relatively easily (some already had been when it was cancelled). Mechanical aspects included a problematical engine installation and undercarriage problems. There were difficulties with management both in trying to blend together two previously independent companies and the obsession with letting committees make decisions; regular escalations in the specification's limits, both in capability and performance, when a simplified aircraft would have helped; and an overall lack of financial control. The project's unhappy life was compounded by the fact that both Government and industry were still learning how to handle the procurement of such complex weapon systems. In the end TSR.2 became far too expensive; a great sum had been spent and more was needed. I am the last person to support Wilson and his Government but one can sympathise with the decision to cancel. There was no possible decision that could please everyone.

All Government papers examined by the author suggest cost was by far the main reason for cancelling TSR.2; it was too expensive and had to be stopped, F-111 would be much cheaper. For the workforce, it must have been ghastly to have created such an incredibly capable and beautiful aircraft, which flew so well, only to see it pass directly to the scrap heap. The aircraft required no modifications to its basic aerodynamics or controls but evidence suggests that the rear fuselage needed some redesign to allow the engine change unit (ECU – the engine and its systems) to fit better. In addition the very early first-generation solid-state electronics fitted in the aircraft were complex for their day and may have created problems. TSR.2 introduced many new avionic systems but suffered through the new technology in general being developed on the back of the programme, rather than under separately financed research. TSR.2's airframe was also frozen just before the advent of new, miniaturised electronics which would use up less space in an airframe.

The first two F-111Ks seen in quarantine at maximum assembly on 20th March 1968, pending a decision on their future. They were eventually reduced to spares. General Dynamics via Joe Cherrie

Back in the 1950s the role of the strategic bomber was clear and so was that of the close support aircraft such as the wartime Hawker Typhoon fighter-bomber. But the gap in the middle was often difficult to define. The wartime light bomber, represented by types like the North American B-25 Mitchell in RAF service, faded away after 1945 but a very light 'multi-role' bomber like the Mosquito, 'the maid of all work', was still wanted to hit tactical targets and airfields. Canberra was really a jet Mosquito but improved defences meant a replacement might be needed from the mid-1950s. The Suez crisis showed that it was but this presented big problems since no-one could really decide just what form it should take and how much money should be spent on it.

A Foreign Office telegram dated 10th April 1963 noted that TSR.2 was not, and never intended to be, the basis of a British deterrent. TSR.2 would have delivered nuclear bombs very well but it was a very expensive way of carrying iron bombs. The type was first seen as a relatively simple aircraft but from the late 1950s the concept became progressively more complex. As a result, TSR.2 outgrew its original tactical duties and eventually nuclear weapons became its primary armament to fulfil a strategic role as well, an idea which, at first, was never intended. The weapon bay was designed around two standard UK nuclear bombs, although it could also carry six 1,000lb (454kg) conventional bombs. This moved it up from secondary system level but giving it the capability to penetrate Soviet airspace increased the price and brought rows over range.

However, had say 120 TSR.2s been put into service, one suspects that they would have given the Russians many sleepless nights; they would certainly have cost a lot of money and effort to counter. Official requirements never state that a new bomber should force the enemy to have to double his efforts and expenditure to provide a defence against it. The Soviet Su-24 *Fencer*, a similar and formidable aircraft, caused grave concern in the West with its ability to penetrate NATO defences. Fortunately, Britain did not get involved in a major war with the Soviet Union, so the TSR.2 was not really missed by the Service. In the end, after all the criticism given to the Buccaneer, the RAF received that aircraft, and then the Tornado, and both have done the Service proud. TSR.2 was in many ways ahead of its time but Tornado benefited from the design work undertaken on it.

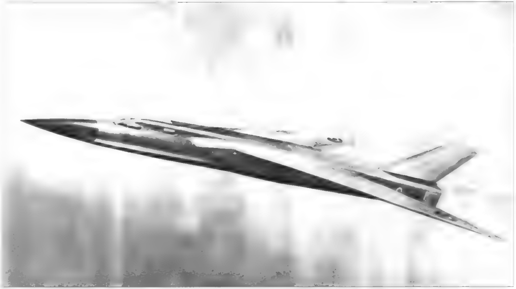
Way back in April 1953, the Operational Requirements Branch was grappling with the replacement for the Canberra and in particular a requirement for Mach 1.4 speed together with the weight problem that created. On 28th April P Broad, DDOR1, noted: 'We will not be able to afford a new light bomber if it is going to be larger than 60,000lb (27,216kg) all-up-weight when carrying a bomb load of not more than 10,000lb (4,536kg)'. He felt the solution was a cruising speed of between Mach 0.8 and 0.9 with the capability of short bursts at more than Mach 1. His words were very prophetic; the type he described resembled Buccaneer rather than TSR.2; he knew we could not afford a large aeroplane. The fighter-bomber eventually evolved into today's Harrier and Jaguar light ground attack and tactical support types; the light bomber became the heavier interdictor strike aircraft, represented by Tornado, carrying weapons designed to hit bigger targets like airfields and bridges.

Strike Aircraft Projects – Estimated Data

Project	Span ft in (m)	Length ft in (m)	Wing Area ft² (m²)	t/c %	All-Up-Weight lb (kg)	Powerplant Thrust lb (kN)	Max Speed mph (km/h) Height ft (m)	Weapon Load lb (kg)
HSA Combined Strike Aircraft	45 10 (14.0)	74 3 (22.6)	600 (55.8)	5 root 4 tip	74,870 (33,961) (1,000nm)	2 x Ol.22R Olympus	Mach 1+(?) at sea level, Mach 2(?) at altitude	Red Beard, 2 x Bullpup, 3 x 1,000 (454), 24 x 3in or 90 x 2in RPs internal, 4 x 1,000 (454) under wings; 2 x 37x 2in RP packs at wing tips
Hawker P.1121 (7.58)	37 0 (11.3)	67 8 (20.6)	474 (44.1)	?	50,710 (23,002) (normal - two drop tanks)	1 x Ol.21R Olympus 29,000 (128.9) reheat	Mach 1.3 979 (1,575) at sea level, Mach 2.2 above 36,000 (10,973) (engine limit)	Red Beard or 2 x 1,000 (454) under fuselage; 4 x 1,000 (454), 36 x 3in or 148 x 2in RPs under wings
BAC Type 571 (TSR.2 Datum) (7.59)	37 1 (11.3)	84 1 (25.6)	697 (64.8)	3.6 root	85,070 (38,588)	2 x Ol.22R Olympus 16,600 (73.8), 30,600 (136.0) reheat	Mach 1+ at sea level, Mach 2+ at altitude	(Spec. RB.192D) 1 x TNW, 6 x 1,000 (454) internal; 2 x TNW, 4 x 1,000 (454), 4 x Bullpup, 24 x 3in or 148 x 2in RPs external
TSR.2 (Flown)	37 1 . (11.3)	89 0.5 (27.1)	703 (65.4)	c3.6	95,900 (43,500) normal, 105,000 (47,628) overload	2 x Ol.22R Olympus 19,600 (87.1), 30,610 (136.0) reheat	cMach 1.1 at sea level, Mach 2.05 at 36,000 (10,973); best achieved Mach 1.13 at 30,000 (9,144)	2 x WE.177 or 6 x 1,000 (454) internal, 2 x WE.177, 4 x 1,000 (454), 4 x AS.30 or 148 x 2in RPs under wings

Chapter Nine

VG and OR.346



Artist's impressions of the Vickers Type 581 ER.206/3 (3.60). Eric Morgan Collection

Swing Wings and Multi-Role: 1959 to 1964

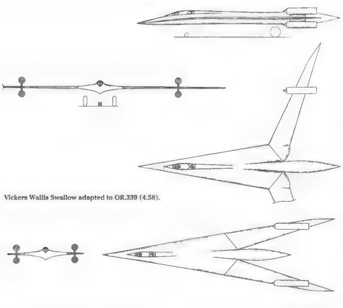
Despite the policy presented to the British aircraft industry by the 1957 Defence White Paper, two years later work began on another advanced military aeroplane. This was covered by Operational Requirement OR.346 and was primarily intended to assess the application of some variable sweep work by Vickers to a strike fighter. However, the Hawker Siddeley Group also produced its own ideas to OR.346.

Vickers-Armstrong Swallow

In the 1950s Vickers' R&D Department at Weybridge became involved with variable geometry swing-wing aeroplanes through the work of designer Barnes Wallis. Wallis' first thoughts on the subject, using jet propulsion, dated back to the start of the Second World War and in 1943 he realised that ranges and speeds might be obtained far beyond anything hitherto achieved. After working on a VG wing project called Wild Goose, his studies came under the all-embracing title of Swallow. These initially covered civil applications but the need to continue to find funding ensured some military variants appeared as well. Vickers patented the Swallow principle in January 1954 and construction of a radio-controlled subsonic free-flying model began in April. In September the first flight was made of a direct-controlled flying model at Predannack airfield and the following year saw the start of subsonic tunnel tests and then supersonic free-flight trails at Larkhill.

Alongside the theoretical study, tunnel testing and the use of large scale models, several aircraft project studies were made and some mechanical parts associated with sweeping wings were manufactured and tested, the latter including an oil-lubricated pivot bearing in August 1956 and a dry bearing wing pivot in May 1958. In October 1955 a design study was prepared to R.156T and a second four months later based on OR.330; in 1957 two research aircraft of 10,000lb (4,536kg) and 25,000lb (11,340kg) weight were proposed. The MoS was actively engaged through this period but after the 1957 White Paper all financial support was withdrawn and the work at Predannack ceased in June. In April 1958 Wallis completed a brochure for a Swallow bomber based on the requirements of OR.339.

Wallis claimed that the Swallow configuration was pre-eminently suited to combine the smallest possible all-up-weight with high performance, very long range and low take-off and landing speeds. Its dimensions, and those of a long-range supersonic fighter, were identical to a planned research aircraft. Various studies had revealed the advantages of the highly swept arrowhead configuration for



Vickers Wallis Swallow adapted to OR.339 (4.58).

supersonic flight but it was incapable of take-off and landing, so the wings would have to be swept forward for those actions to take place. The engines, four Bristol BE.38 'Supersonic' Orpheus, were mounted in nacelles above and below the outer wing and one Red Beard was carried in a rear fuselage housing. Official assessment suggested that developing a Swallow bomber from ITP to CA Release would take a minimum of ten years, and perhaps fourteen, which was far too long.

Vickers continued alone until joint discussions on a VG programme were held between the MoA, Vickers and the United States Mutual Weapons Development Programme (MWDP) in the spring of 1958. The American finance was vital but they had also flown two experimental VG prototypes in the early 1950s, the Bell X-5 and the Grumman XF10F Jaguar. In November 1958 a joint Ministry/Vickers team visited NASA's Langley Field to discuss the areas to be covered by each party. An agreement was reached between MoA and MWDP in February 1959 for a one-year joint research programme to assess the feasibility for operational applications of the Swallow variable geometry principle; Vickers received a contract in May. The programme was split into two parts: further research and then a project study to a Service requirement for which an interim brochure was to be ready by 31st October and a more complete proposal by 31st January 1960.

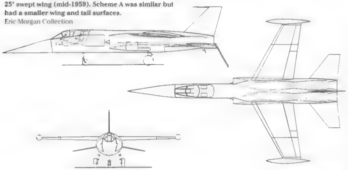
OR.346 and ER.206

On 17th March 1959 a new Naval Staff Target outlined a multi-purpose strike fighter and reconnaissance aircraft to enter service in 1970, and on 3rd April discussions began between the Ministry and the Air and Naval Staffs which led to the issue of Joint Naval Air Staff Target OR.346 as the basis for a research programme. The Navy amplified this with a draft OR for a carrier-based aircraft of 50,000lb (22,680kg) maximum all-up-weight. In the primary tactical strike role this would take 6,000lb (2,722kg) of bombs over a 1,000nm (1,852km) radius of action (with the last 200nm [370km] to the target flown at low level) and as an interceptor carry four AAMs to intercept and destroy an intruder flying at Mach 2.0 at 80,000ft (24,384m) off a combat air patrol of four hours. In addition low take-off and approach speeds of the order of 80 knots (92mph [148km/h]) were desirable.

High supersonic speed (Mach 2.5+), long range at high subsonic speed, a 'low-altitude capability' and a reconnaissance capability were also requested. The ability to switch from one role to another at fairly short notice (12 to 24 hours) was also important. The draft naval OR was subsequently used for a variable sweep design study under experimental research specification ER.206. The primary task for all of these projects was strike.

In June 1959 the MWDP's John Stack gave the results of NASA's wind tunnel tests on the original Swallow with engines on the wings and a submerged body; they were not good. The arrow wing did not give the expected high value of L/D (lift/drag ratio) while inherent pitch-up instability was experienced at low speeds. NASA had made a series of alterations to cure this and eventually arrived at an arrangement which departed from the arrowhead tailless Swallow to a more conventional aircraft with fuselage-mounted engines and low horizontal tail. Stack described this alternative VG strike aircraft concept (now under comprehensive test by NASA) and it was eventually to lead to the F-111. These changes to the VG layout brought an end to Wallis's involvement with the project.

Vickers Scheme B adaptation of TSR.2 to ER.206 with 25° swept wing (mid-1959). Scheme A was similar but had a smaller wing and tail surfaces. Eric Morgan Collection



Vickers-Armstrong ER.206 Projects (Type 581)

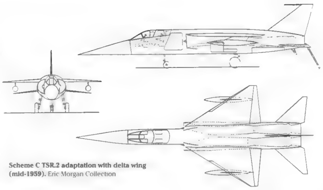
ER.206/1

Vickers' work to the Joint OR commenced on 1st May 1959. Since the naval strike sortie was very similar to that laid down for TSR.2 (but with a bigger bomb load), it was felt useful to see to what extent a TSR.2 type could be adapted by scaling it down in size; three versions were assessed. These could be in service in 1966 but they used light alloy as the main structural material which limited the usable Mach number to about 2.5. Schemes A and B had near-identical fuselages but with high-mounted wings of different area; Scheme C had a TSR.2-style delta. Air was bled from the compressors to both leading edge and trailing-edge flaps to reduce take-off and landing speeds and each had an all-moving tail and fin. However, the 25° sweep versions had ailerons while the delta, like TSR.2, achieved roll control by differential movement of the port and starboard halves of the tailplane. A and B had tip tanks which would be dumped before going into action.

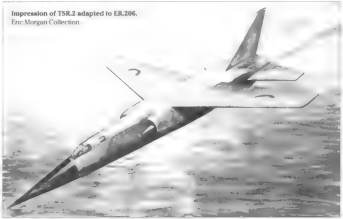
Alternative engines were twin Bristol BE.61 bypass units, RB.142/4 bypass units scaled to half thrust or four RB.153 straight jet engines. The half-scale RB.142/4 showed up best and was used in the performance presentation. For strike the electronics were closely based on TSR.2 and weapons were carried internally and on external pylons; for interception, two new 12ft (3.66m) long semi-active AAMs were housed in the weapon bay while the forward-looking terrain clearance and the sideways-looking radar were replaced by an AI set with a 36in (91cm) dish. None of these arrangements fulfilled the OR completely but this was to be expected since the 50,000lb (22,680kg) maximum weight was around 60% of TSR.2's while OR.346's task was more exacting. Efforts to meet the more severe deck requirements by conventional means had led to an inferior sortie performance.

ER.206/2

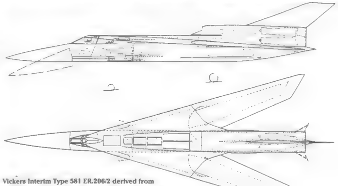
A fairly direct derivative of the arrow-wing Swallow was evaluated in the October Interim Report. The biggest change had been to put the engines, crew and equipment into a fuselage and the report indicated that the OR could be met by a variable geometry aircraft of about 50,000lb take-off weight but it was not yet possible to state the best configuration, principally through a lack of knowledge regarding low-speed longitudinal stability. This aircraft had four RB.153s arranged in a four-square block on the upper rear fuselage which formed an independent



Scheme C TSR.2 adaptation with delta wing (mid-1959). Eric Morgan Collection



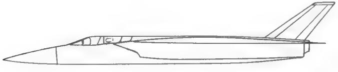
Impression of TSR.2 adapted to ER.206. Eric Morgan Collection

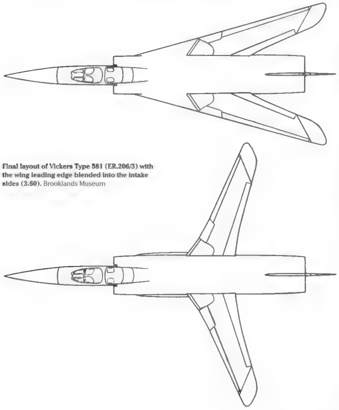


Vickers Interim Type 581 ER.206/2 derived from the Swallow (10.59). Note how the arrow wing stretches as far as the cockpit. Eric Morgan Collection

unit from the main structure; air was supplied from intakes above the wing.

Blown flaps were used for low-speed landing and the resulting nose down moment was offset by two Rolls-Royce lift engines placed behind the pilot; their intakes folded into the wing leading edge. The largest practical forward-looking radar with a 36in dish was housed in the nose while the other equipment was arranged along the lines of TSR.2 with the sideways-looking navigation radar stowed under the pilot's floor. The bomb bay occupied the fuselage beneath the wing centre section and housed all the weapons including semi-active AAMs; nothing was carried externally. A conventional structure was used except for the wing centre section, the wing itself consisting of a highly swept delta forewing and two afterwings pivoted so that they could be swept from 25° to 75°; both forewing and centre section were mounted on top of a fuselage of circular cross-section.





Final layout of Vickers Type 581 (ER.206/3) with the wing leading edge blended into the intake sides (3.60). Brooklands Museum

Maximum speed was Mach 3.0 subject to the limits of the materials used and an alternative layout had four side-by-side engines fed by large side intakes.

ER.206/3

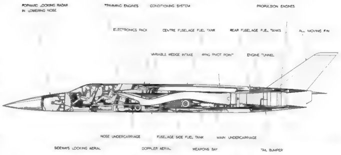
The deadline to complete the full feasibility study was extended to March 1960. Vickers reported that VG offered a very considerable advance in aircraft capability and, except for a reduction in weapon load, OR.346's 1970 in-service date could be met at an all-up-weight not exceeding 50,000lb, provided that engines scaled from existing types to match the OR were available. There was, however, disagreement as to whether the stability and control problems could be met with a tailless aircraft – NASA supported a fairly conventional layout with a tail, the MoA had an open mind but tended to favour a tail while Vickers felt that, on the strength of the work so far, nothing had come to light to show that a tailplane was essential from a control and stability point of view. The penalty for fitting a tail would be increased structure weight and a lower L/D which needed more fuel and thus gave a heavier aeroplane. Hence, Vickers' brochure discussed a tailless configuration again designed primarily around the naval requirement.

ER.206/2's sweep angles and all-moving fin were retained and control was effected by wing tip elevons. Again, in the absence of a tailplane, the flaps produced a nose-down pitching movement which had to be balanced by duplicated lightweight lift engines placed just aft of the navigator's seat bulkhead, control of which would be automatic and coupled to the elevons. The trimming engines only ran during take-off and landing and their folding intakes and exhaust doors lay respectively on the top and bottom of the fuselage, the exhaust gases being directed away from the surrounding structure and the nosewheel. Tunnel tests supported using elevons for longitudinal and lateral control while the addition of under fuselage strakes together with the central fin gave acceptable directional stability. The elevons could be inclined so that useful control was available at all angles of sweep.

Leading-edge and trailing-edge flaps with boundary layer control were proposed. Exploratory tests had found a method whereby the inherent pitch-up instability detected by NASA in the Swallow was delayed to a point where a sufficient safety margin could be allowed. This was achieved by getting rid of the forewing as a lift producer at low speeds by either folding it along the intake duct side (the favoured alternative) or retracting it into the fuselage as the afterwings moved forward. Leading-edge slats or a blown drooped leading edge plus blown flaps could be fitted. The fuselage was the minimum size to take the crew, equipment and stores while fuel was carried in the forewing, afterwings and fuselage. The nose could be drooped in flight to provide a good forward view for landing.

Internal detail of the ER.206/3. Brooklands Museum

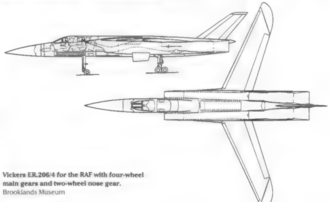
Artist's impressions of the Vickers Type 581 ER.206/3 (3.60). Eric Morgan Collection



Studies between a simple jet, a bypass engine and a reheated aft fan engine had shown the medium bypass unit was generally the best. Two 0.7 scale reheated RB.163s placed either side of the weapons bay had horizontal variable geometry wedge intakes, a fully variable integral reheat system and aerodynamic ejector-type nozzles. Weapons were carried internally in the large bay beneath the wing (which could also take auxiliary fuel tanks) and the naval version would have high-pressure wheels on a conventional undercarriage, catapulting hooks and an arrestor sting. (Most naval OR.346 projects were given folding wings and noses.)

There were two crew and the interceptor's 36in (91cm) radar dish, which had a search range of about 70nm (130km), was again housed in the nose. The forward-looking radar's primary functions were terrain following, radar ranging for attack, airfield homing and blind approach. These could be performed by a much smaller radar than was necessary for long-range interception so in the strike role the set was replaced by a TSR.2-type radar in the same radome. A Doppler and inertial platform produced data for the computing system (i.e. ground speed and drift and reference of azimuth, elevation and roll). The sideways-looking radar provided fix information in blind conditions at low and high altitude, which enabled corrections to be made to the Doppler/inertial platform/computer system, and also supplied reconnaissance information to go with an optional self-contained recce pack.

The weights quoted were for an aircraft capable of continuous operation at Mach 2 with short bursts at Mach 2.5. Range with a 4,000lb (1,814kg) load was 1,000nm (1,852km); internal fuel totalled 12,700lb (5,761kg). To meet the 1970 in-service date it was essential that work on the VG aircraft should not be allowed to run down and Vickers outlined a future programme based on the first flight of a pre-development aircraft in mid-1964.



Vickers ER.206/4 for the RAF with four-wheel main gears and two-wheel nose gear. Brooklands Museum

ER.206.4
Vickers felt that removing the naval aircraft's severe weight restriction could make for a very attractive RAF version and the company completed a study in May 1960. The main differences between the Navy and RAF requirements were that the former needed *slow* take-off and landing speeds, low all-up-weight and small size while the RAF wanted a *short* take-off and landing capability from semi-prepared strips. Otherwise the performance limits were similar. A 'denavalised' RAF version would have low-pressure tyres and be suitable for operation from semi-prepared airfields, and without the limits of carrier landing it could carry the full six 1,000lb (454kg) bomb load and more fuel. A 3,000lb (1,361kg) weapon load was assumed for the interceptor role and it was noted that the ability to loiter subsonically, coupled with efficient flight at supersonic speeds, was one advantage of VG. Design diving speed was 800 knots (921mph [1,482km/h]) EAS or Mach 1.21 at sea level. Two RB.165s were fitted which had the same characteristics as the 0.8 scale RB.163.

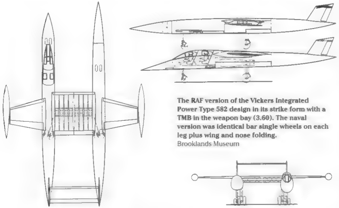
Vickers Type 582

The adapted TSR.2 layouts produced as alternatives to Swallow had proved inadequate to meet OR.346, the preferred alternative having no potential for weight growth. After considering other possibilities a detailed study was made of a more advanced alternative design in which the power installation was integrated with the wing structure. The report concluded that a total military load of 8,000lb (3,629kg) could be carried within the 50,000lb (22,680kg) limit. With a twin fuselage and a structure consisting mainly of FV520 steel honeycomb it was capable of very high Mach numbers while also being able to take off and land at low speeds thanks to the use of the jet flap principle where the exhaust gases were blown out of the wing trailing edge (this idea was tested on the Hunting H.126 research aircraft from March 1963 but only at low speeds). To meet the 1970 in-service date a development batch would be required by 1966; new engines were an important feature but the RB.153 could be used for early development flying.

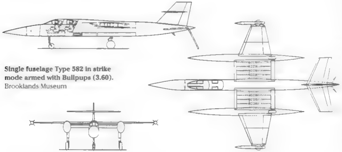
Eight reheated 1,800lb (8kN) dry thrust engines of similar design to the RB.163 were housed in the wing centre section. Flaps on the upper and lower surfaces of the wing leading edge and trailing edge would vary the intake and exhaust geometry to cover the range of flight speeds, including deflecting the exhaust downwards for take-off and landing. The outer wing panels were equipped with blown leading-edge and trailing-edge flaps and folded downwards for carrier stowage while the two fins were connected by an all-moving tailplane equipped with a blown flap for use during slow flying. The crew was located in the port fuselage, the radar and other electronics in the starboard fuselage. Fuel and weapons were shared between the two with enough provided for a strike radius of 1,200nm (2,224km) when carrying a tactical atomic weapon. Alternative low and medium-altitude reconnaissance packs were available and an airborne early warning (AEW) Type 582 was also proposed.

A four-leg undercarriage was fitted which on the naval version had single main and nosewheels; the RAF's had a pair of wheels on each leg with low-pressure tyres and also two 200gal (909lit) wing tip tanks which on a strike mission were jettisoned before descending to low altitude. A four-hour patrol endurance was provided for the interceptor role. Four semi-active AAMs were carried, their guidance being derived from the large AI radar in the starboard nose. This aircraft was especially suited for 'off the deck' interception and with the jet flap operating, estimated speeds were 100 knots (115mph [185km/h]) EAS at take-off, 106 knots (122mph [196km/h]) on approach. Mach 2.5 ceiling was 60,000ft (18,288m) at 40,000lb (18,144kg) weight, 65,000ft (19,812m) at 31,000lb (14,062kg). Rather less structural analysis and tunnel testing was carried out on the 582 compared to the Vickers VG designs.

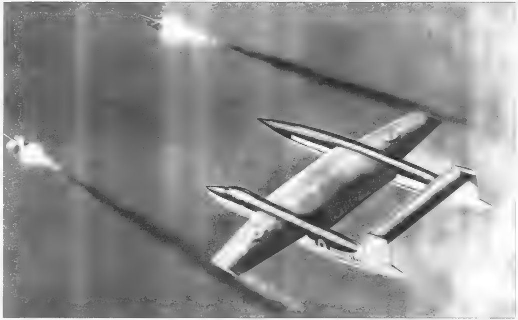
An alternative, single-fuselage layout was briefly studied but it gave more drag than the twin which forced an increase in fuel and thus total weight; however, the smaller strike radar and radome removed the need for a drooping nose and the single fuselage also presented some advantage in sideways view over the twin. It retained the good carrier performance of the twin-fuselage design but for the same total weight the sortie performance was not quite as good. However, without the take-off weight limit Vickers felt the single fuselage presented the better choice for the RAF.



The RAF version of the Vickers Integrated Power Type 582 design in its strike form with a TMB in the weapon bay (3.60). The naval version was identical bar single wheels on each leg plus wing and nose folding.
Brooklands Museum



Single fuselage Type 582 in strike mode armed with Bullpups (3.60).
Brooklands Museum



Impression of the Naval Type 582 as a high-altitude interceptor, seen firing two AAMs.
Brooklands Museum

The MoA assessed Vickers' results in June and acknowledged that the VG types offered considerable advantages over conventional fixed-wing aircraft, particularly in approach speed. All of these projects were capable of cruising supersonically at the expense of range. The 582 had a lighter combined structure and installed powerplant weight but inferior cruise aerodynamics and gust response (the VG's gust response was itself slightly worse than TSR.2's). Nevertheless it was felt that Vickers had produced a potential competitor to variable sweep which might take less time to develop, but its success would depend on the new small engines having the assumed performance, while their introduction might take too long. RRE thought Vickers' approach to the many problems of designing a weapons system was very naive but the twin-fuselage Integrated Power airframe did offer big advantages to the radar designer in that it allowed the use of a large aerial.

The results of the Vickers VG work were summarised as follows:

1. The proposed Swallow configuration was found to present so many problems, especially as regards safety in flight, control and aerodynamics, that it was not feasible to adopt it and no further work was carried out.
2. The joint research programme, however, demonstrated that the application of variable sweep wings for certain military uses gave considerable improvements in performance, particularly approach speeds on landing.
3. The ingenious spherical pivot (covered by a Vickers patent) which Dr. Wallis had designed for a variable sweeping wing might well be found to be an important feature, certainly as regards the application of VG to UK military types.

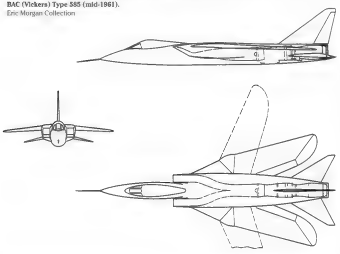
A further programme of VG work by Vickers, financed by the MoA without American participation, began on 1st August 1960 and covered the construction and testing of more tunnel models, the structural testing of a sweep mechanism and an engineering assessment of the variable sweep part of an aircraft. This suggested that the potential advantages of VG without a tailplane could represent the most attractive advanced solution in the strike fighter field. In October, discussions between the Air Staff and MoA began for a new Air Staff Target (AST) to cover the application of VG to a wide range of future requirements. Three months later the R&D Board turned down an MoA submission to further extend Vickers' research because it felt that the next step should be to build a VG aeroplane; both the Services and the Aeronautical Research Council pressed strongly for a research aircraft programme.

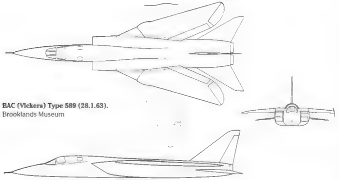
Adequate funds were allocated in the 1962/63 and 1963/64 estimates for VG research and the Ministry's R&D Board agreed in principle to a programme of two experimental aircraft (much of Vickers' work had been self-financed). On 1st April 1962 a design study contract was placed with Vickers for an experimental VG aircraft (the Type 589), a step confirmed in the House of Commons on 9th July by Mr Woodhouse, Minister of Aviation. In fact the company was to put together a family of VG projects which is described shortly.

OR.346 was to influence aircraft design for some time to come but by 1961 the Navy's need to replace several of its aircraft was also a factor. In May discussions began for replacing the Sea Vixen fighter and the Buccaneer by an OR.346 type in the 1970 to 1972 period. Gp Capt T Witt, DDOR1, noted on 13th July that the Naval Staff was still fairly wedded to the OR.346 concept and the development of a special naval aircraft, while the Admiralty had designed a new carrier around the Vickers VG aircraft to OR.346. The Ministry of Aviation was an ally because it was 'desperate to go ahead with a VG aircraft'.

In the meantime the RAF was looking at a TSR.2 replacement and in the summer of 1961, after a request from Controller Aircraft who wanted a focus point, the Air Staff hurriedly raised OR.354. This called for an in-service date of about 1975 but when it was realised that the Buccaneer successor was not required until 1974, OR.354 was substituted by OR.355 (first draft October 1961) which detailed a TSR.2 and Buccaneer replacement; by August 1964 this had been succeeded by AST.355. Handley Page completed a brief study to OR.354 in December 1961 and designer Godfrey Lee reported that they had compared a 60,000lb (27,216kg) slim delta wing, a straight-wing type, a swept wing and a VG aircraft. Calculations showed that the first two were non-starters because of an impossibly low percentage structure weight but, despite a 5% weight increase from the swing-wing mechanism, the VG arrangement was, on the whole, the best solution.

BAC (Vickers) Type 585 (mid-1961).
Eric Morgan Collection





BAC (Vickers) Type 589 (28.1.63).
Brooklands Museum

BAC (Vickers) Type 583

This project was more of a fighter than a bomber and is described in *BSP: Fighters* but it also acted as a pre-development research aircraft to OR.346. In July 1964 Vickers (now BAC) noted that whereas OR.346 could only operate from new carriers, in current form the 583 provided the required multi-role capability and could also be flown by existing carriers having BS4 (151ft [46.0m]) catapults and uprated Mk.13 arrestor gear. The claim was made after the Royal Navy announced its intention to order the McDonnell F-4 Phantom and a comparison between the two types indicated that the Type 583 would be superior. A version of 583 with lift jets was also suggested for OR.355.

BAC (Vickers) Type 585

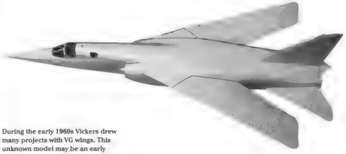
Type 585 began as a naval derivative of the Type 584 NATO NBMR.3 proposal (see Chapter Ten) but eventually settled down into a single-engine close support aircraft. It carried 7,000lb (3,175kg) of internal fuel and its supersonic cruise duration totalled ten minutes at Mach 2.0, but this study was relatively brief.

BAC (Vickers) Type 588

As part of the work to the NBMR.3 strike reconnaissance competition, draft proposals were submitted at the request of the MoA for two research aeroplanes. One would be based on current fighters but fitted with VG wings under Type 588, the other was a new aircraft resembling the OR.346 design called Type 589. Because of its proven supersonic capability, the great majority of the Type 588 work centred on modifying the English Electric P.1B Lightning, although in June 1961 a brief study was made for converting the Supermarine Swift. Changes were confined to the wings with the hinge position about one-third span out from the root. Preliminary tunnel tests confirmed the feasibility of part-span variable sweep wings applied to the Lightning and part-span flaps and slats gave satisfactory results, with a strong pitch down at the stall with the slats extended. However the MoA considered that to ask for money for a VG Lightning would jeopardise financial support for an all-new research aircraft, despite the fact that it would cost about one-tenth of the price of the new type, so from January 1962 Vickers pushed for financial sanction for the Type 589. VG Lightning work ended on 3rd February 1962.

BAC (Vickers) Type 589

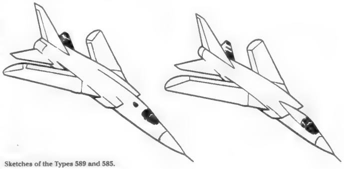
Two all-new variable sweep prototype research aircraft were planned to extend the data collected by the Type 588 and a preliminary brochure was completed in February 1963. Since the Type 589 was projected against future RAF and RN requirements for the 1970s it could be readily developed into an operational aeroplane. However, emphasis was placed on pure research although the Type 589 had two engines and two crew and the general layout of a typical strike aircraft. As such they would be expensive machines and the twin-engine layout was felt justified on the grounds of reliability. In an effort to keep down costs existing components were used where possible including TSR.2's cockpit hood, a high percentage of TSR.2 system components and a nose undercarriage fitted complete from a Scimitar.



During the early 1960s Vickers drew many projects with VG wings. This unknown model may be an early version of the Type 589; bar the intakes and horizontal tail, it does look very similar.

Vickers had pressed for a contract to build a VG aeroplane and the American move to order a production aircraft based on the work done by Vickers in this field (the TFX/F-111) substantiated the company's faith in this system. The Americans too had taken a long time in deciding to proceed with a VG aircraft and it was felt that if Britain wished to do the same it was essential that it obtained the necessary design experience now; variable sweep could then be applied to future projects. Type 589's objectives would include proof of the engineering design, development of VG aerodynamics, the reliability of those systems peculiar to a VG configuration, understanding of the weight penalties and the aeroelastic and stability problems over a wide speed range, and the analysis of structural loads.

Three wing positions would cover the aircraft's flight range although it could be flown at any intermediate angle of sweep. The forward position would be used for take-off, landing and subsonic cruise, a higher sweep for transonic flight and maximum sweep for supersonic (Mach 1.4+) flight. Two Avon engines similar to those used in the EE Lightning powered the Type 589 but, owing to the greater air bleed demands, the compressor casing would be changed for one dimensionally similar to the Scimitar's Avon RA.24. The air intakes were of the horizontal wedge type with a variable throat and variable exhausts were fitted to the reheat pipes; RB.168s were also under consideration. Type 589 carried 14,900lb (6,759kg) of internal fuel and exper-



Sketches of the Types 589 and 585.
Brooklands Museum

imental equipment only but allowances were made to fit more advanced equipment at a later date.

The wings were swept by two hydraulic jacks mechanically interconnected. Sweep position could be varied automatically with Mach number and height but the pilot could override the automatic variation. Control features included leading-edge slats and blown trailing-edge flaps (to give a high lift coefficient for take-off and landing), wing tip ailerons, an all-moving tail and a rudder mounted on a fixed fin. The undercarriage had single-wheel main gears and was designed for operation from both aircraft carriers and concrete runways; launching hooks and arrestor gear were also fitted. Basic structure was in light alloy except areas experiencing extreme conditions; the use of special light alloys and steels was avoided. Maximum sea level rate of climb was 30,000ft/min (9,144m/min), absolute ceiling was 55,400ft (16,886m) and supersonic cruise duration was 15 minutes at Mach 2.0.

The Type 590 was intended to be a production strike version of the 589 aimed at OR.346 and it formed the naval objective of the 589's research. At 31st October 1962 the 590's take-off weight in the strike role stood at 47,846lb (21,703kg); as an interceptor this became 48,070lb (21,805kg). Work was completed on both projects in June 1963. The Type 591 of 1962 was seen as a high Mach number development of the Type 589 to OR.355 and a long-term objective for a joint RN/RAF design with service entry in 1975.

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Eventually the Navy split its Sea Vixen replacement into a separate document, AW.406/OR.356 (this is described in *BSP: Fighters*). It was also agreed that the RAF's tactical requirements to the end of the 1970s could be settled by the TSR.2 and the P.1154 (see Chapter Ten) and so it was too soon to start work on a successor. When the 1962 project study was awarded to Vickers it was hoped that after 12 months the Ministry would be in a position to proceed with the design of an experimental VG aircraft whose characteristics would be based firmly on those of a foreseen military type. However, on 25th January 1963 the Defence Research Policy Committee reported that the changed circumstances regarding the development of military types meant the case for building an experimental variable sweep aircraft as a lead-in had diminished.

It was still generally agreed that a research type would help the development of an operational aircraft, but the experiment would be very costly (£10m to £20m) and its value would be much less if the final operational aircraft differed markedly from the experimental type or if it was considerably delayed. Both of these circumstances were now likely to arise. Hence the Committee had concluded that this stage of development must be deferred although work could continue on the engineering, structural and aerodynamic problems of VG while studies could be extended to embrace transport and maritime reconnaissance designs. This meant that the Type 589 would not be built. By April 1964 Weybridge was working on a smaller research aeroplane called the Type 593, but later that year the company's VG work was transferred to its BAC sister company at Warton (formerly English Electric), a move which eventually brought forth the Tornado. This story continues in Chapters 13 and 14 (Vickers became part of BAC in 1960 but was still called Vickers, even in Government documents, for several years afterwards).

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Vickers was not the only company to work to the joint Bi-Service OR.346. On 13th December 1960 the Admiralty gave a presentation to Hawker Siddeley representatives on the future of Naval air operations. New carriers which were to be in service in 1970 would require the OR.346 multi-purpose Mach 2 interceptor strike aircraft which Hawker noted was, in effect, a TSR.2 limited to 50,000lb (22,680kg) all-up-weight. In February 1961 a meeting between Blackburn, de Havilland (DH) and Hawker, chaired by S D Davies, discussed the 'new combined OR.346' and agreed that as DH had progressed further than any other member of the Hawker Siddeley Group it should be allowed to concentrate on this project, while using the experience of the other companies. An OR.346 Group team was formed under de Havilland's W A 'Bill' Tamblin and meetings began on 16th June. However, separate investigations to OR.346 were initiated at Brough, Hatfield and Kingston which were also looked at as alternative layouts to the P.1154 supersonic VTOL aircraft described in Chapter Ten.

HSA (Blackburn) B.123

Brough's first thoughts on this strike/interceptor, which could be considered as a successor to the Buccaneer for the early 1970s, were broadly based on OR.346's naval aspects; the company of course specialised in naval aircraft. The main objectives included take-off weight as near to 50,000lb as possible, a strike radius of 1,000nm (1,853km) at Mach 0.95 with 100nm (185km) at low level into and away from the target, a top speed for the 'clean' aircraft of greater than Mach 2, and a low approach speed (80 to 100 knots [92mph to 115mph/148km/h to 185km/h]). VG was rejected because of Vickers' efforts in the field so, for the present, a delta was adopted for altitude cruise at Mach 0.95. The best powerplant was two RR Speys. By arranging to deflect some of the thrust downwards behind the CofG and to balance it by further downward thrust from lightweight vertical lift units ahead of the CofG, a substantial contribution to lift for the low approach speed could be obtained.

It was apparent that the next-generation strike aircraft would have to fly to and from the target through missile-defended areas, so it would make the maximum use of natural cover by keeping very near the ground. In the company's view, the high longitudinal response and damping in pitch necessary to follow the terrain accurately were extremely difficult to obtain on a delta wing without using a tailplane or foreplane. The latter gave some advantages since it contributed lift when a gain in height was needed but the total drag, trim difficulties and layout problems led to the choice of a conventional tail. It was unlikely that an aircraft meeting OR.346 would have a take-off weight below 55,000lb to 56,000lb (24,948kg to 25,402kg), so some thought was given to a separate light strike aircraft of about 40,000lb (18,144kg) weight with a reduced load and range which used a single reheated Rolls-Royce Medway.

B.123's structure used aluminium-copper alloys although some steel would be employed for highly stressed components. Because the small t/c ratio gave high spanwise loads while the aerodynamics required accurate contours and a long fatigue life, the wing skins would be machined from solid billets of stretched material. The wings inboard of the fold joints would form large integral fuel tanks and the choice of a delta instead of a trapezium planform gave much-reduced loads across the wing fold hinge and a much lighter wing generally. Fuselage structure would be conventional and the forward-looking radar had a 36in (91cm) dish. In the strike role the 2,000lb (907kg) nuclear bomb would be carried in a ventral pannier; for conventional sorties a larger and longer pannier could hold eleven 1,000lb (454kg) bombs with four more carried on underwing pylons, two per wing in tandem just inside the fold position. The brochure also included a version with a low tail, a lower all-up-weight and overall length reduced to 72ft 6in (22.1m).

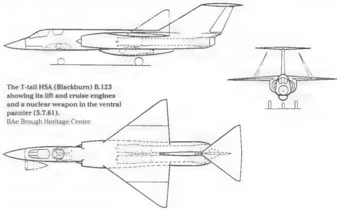
Two months later Brough completed a second B.123 document. The low tail was now preferred but it was realised that in many

respects the requirements of the two Services were incompatible and attempting to reconcile them within a single design would fail to fully satisfy either, again this design stressed the naval side. The RB.168s had two stages of reheat, the first immediately following the rearmost turbine section with the second at the jet pipe outlet. Stage 1 gave a total of 18,000lb (80kN) thrust, at which stage the whole of the engine throughput could be diverted downwards to provide vertical lift; the Stage 2 reheat unit had a variable area exit nozzle. Two horizontally mounted RB.162s were installed behind the cockpit and had deflectors to divert the thrust vertically downwards to provide trimming and additional lift. Fuel was carried in the wing and in two fuselage tanks.

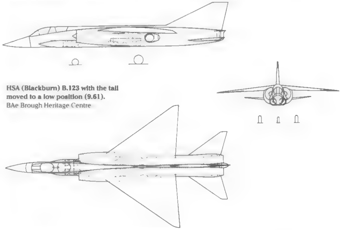
All weaponry was now carried externally, fairings being provided for those stores which needed to be housed in conditioned compartments while the underfuselage items were partially submerged and faired as necessary to cut drag. Six 1,000lb (454kg) bombs could be carried under the fuselage in three rows of two, the 2,000lb (907kg) nuclear store under the centre fuselage, three Bullpups under the fuselage in a one and two plus one under each wing, or one AAM (of a projected delta wing type) or RG.10 ASM under the fuselage and one more under each wing. The method of construction was unchanged.

Cruise at altitude was now at Mach 0.9 and with 22,100lb (10,025kg) of internal fuel targets could be attacked with 4,000lb (1,814kg) of bombs up to 1,000nm (1,853km) from base (maximum internal fuel totalled 24,100lb [10,932kg]). A two-and-a-half-hour Combat Air Patrol could be made with the three AAMs. At 50,000lb weight sea level rate of climb was 42,000ft/min (12,802m/min) with reheat on, 17,500ft/min (5,334m/min) with reheat off; service ceiling at 55,000lb (24,948kg) weight was 54,000ft (16,459m) with reheat on, 45,000ft (13,716m) with reheat off. Maximum carrier weight was 61,380lb (27,842kg) regardless of weapon load, the fuel volume being amended to compensate. At 40,000lb (18,144kg) weight the approach speed for landing was 100 knots (115mph [185km/h]). A forward-looking aerial was used for search, lock-on and weapon release purposes (and air-interception) and a sideways-looking aerial for reconnaissance.

A preliminary study was made for the RAF. This had four more RB.162 lift jets, two in a pack under the propulsion jet pipes and two placed vertically in a forward housing behind the naval version's trim-lift engines. Fuselage length was increased by 10ft (3.05m) and the machine could carry 6,000lb (2,722kg) of bombs for 1,000nm (1,853km). Normal take-off weight was 72,090lb (32,700kg), maximum speeds were unchanged.



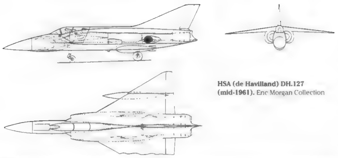
The T-tail HSA (Blackburn) B.123 showing its lift and cruise engines and a nuclear weapon in the ventral pannier (5.7.61).
BAe Brough Heritage Centre



HSA (Blackburn) B.123 with the tail moved to a low position (9.61).
BAe Brough Heritage Centre

HSA (de Havilland) DH.127

A tailless delta designed to meet OR.346 at minimum size and cost and to operate from *Ark Royal* size carriers. It utilised jet lift assistance in the form of deflected thrust, together with twin RB.162 lift engines for trim, to give STOL characteristics and low launch and approach speeds. Particular emphasis was placed on a very large internal fuel capacity for long range and endurance and DH.127 could carry the 2,000lb (907kg) nuclear weapon for a 1,390nm (2,576km) radius of action (1,500nm [2,780km] with drop tanks) or deliver eight 1,000lb (454kg) bombs on a 900nm (1,668km) radius of action; in each case the sea level cruise speed would be Mach 0.9. The 8,000lb (3,629kg) load could also be despatched on a 'cab rank' sortie of 200nm (371km) radius with a stand-off endurance in the target area of up to 2.7 hours. Readily converted to a fighter, at a light load DH.127 could intercept off the deck a Mach 3.0 target at 80,000ft (24,384m) 100nm (185km) from the carrier; at maximum take-off weight it could stay on patrol for nearly four hours.



HSA (de Havilland) DH.127 (mid-1961). Eric Morgan Collection

Model of DH.127. George Cox

DH felt the delta offered certain advantages over VG including the absence of structural complication, a 'fail-safe' wing structure not dependent on a single joint and the ability to carry external loads on the wings. Hawker Kingston's jet lift experience on the P.1127 (see Chapter 10) would be directly applicable as would Avro's work on deltas. Deflecting the propulsive engine's thrust downwards at a small distance behind the CofG to give a vertical thrust component would give substantial lift and a minimum approach speed of just 85 knots (98mph [157km/h]). This thrust lift moment together with the nose-down moment from the wing produced by the flaps was balanced by the two lift engines situated in the front fuselage. A single jet deflection nozzle per engine penetrated through the side of the cowling which in turn was slightly recessed to give clearance for the jet; in normal wingborne flight the compartment was closed by upper and lower doors to form a smooth contour. The RB.168s had inlets with variable geometry conical centre bodies and fully variable convergent nozzles and, by using reheat and the forward trim thrust, a 'free take-off' at 40,000lb (18,144kg) was possible from a carrier moving at speed (31mph [50km/h]) in zero natural wind.

DH.127 had a simple continuous wing to which were attached the fuselage, engines, undercarriage and a single fin with its rudder. It would be made of machined skins with comparatively few internal ribs and spanwise members and had elevon/flap controls. The absence of high-lift devices and freedom from cut-outs enabled a simple structure to be maintained throughout and allowed fuel to be stowed in six integral tanks which, apart from a small space in the leading edge, filled the wing completely from fold to fold. Aluminium-copper alloys were employed for the primary structure because they produced the lowest weight commensurate with the effects of kinetic heating and fatigue damage.

An underfuselage bay could take, semi-submerged, most of the weapons envisaged for DH.127's different roles and a strong point was also provided under each wing for tanks or bombs. The fuselage's contours were preserved by fairings peculiar to the weapons carried. The bay would hold four 1,000lb bombs, the 2,000lb nuclear weapon or four AAMs (either Red Top or its successor); another 1,000lb would go under each wing. The wing tanks, a fin tank and front and rear fuselage tanks housed 2,390gal (10,867lit) of internal fuel and two 250gal (1,137lit) wing pylon tanks and either a 300gal (1,364lit) or 1,050gal (4,774lit) weapon bay tank could also be carried. An alternative recce pack could be housed in the weapons bay. The DH.127 was later renumbered DH.128.

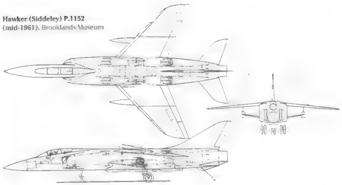
The problems associated with the accurate delivery of a high-explosive attack were well known and no adequate solution had yet been proposed. Analysis of attacks with free-fall bombs had shown this method to be most uncertain and uneconomic. Air-to-ground guided missiles now coming into Service were a considerable improvement but suffered from the fact that the target must be accurately pinpointed before launch and the launch aircraft had to make a diving attack during which it was highly vulnerable. There was a clear requirement for a new weapon and de Havilland's Weapons Research Group was at the time tackling the design of an air-to-ground missile that could be guided with great accuracy through cloud and other weather conditions while permitting the launch aircraft to take evasive action immediately after despatch. This was designated RG.10 and it used television guidance with a head comprising an optical system and a camera. Preliminary studies suggested a weight of about 1,000lb (454kg), a length of 12ft (3.66m), launch at speeds up to Mach 1.5 and a firing range of 9nm (16.7km). This work by the Weapons Research Group appears to have become part of the Anglo-French Martel programme begun in 1964.

Hawker (Siddeley) P.1149 and P.1151

On 16th June 1961 a team from Rolls-Royce's Projects Department visited Kingston to discuss Hawker's P.1149 design which was virtually a Canberra/Buccaneer replacement. It used six lift engines and two vectored thrust propulsive engines but fell considerably short of OR.346 in that its weapon and range capabilities had been sacrificed to a certain extent to achieve a vertical take-off at light loads. All of Hawker's projects to OR.346 were large and complex affairs. P.1151 was a supersonic jet flap type with four reheated RB.153s stacked in pairs along the fuselage sides, the jet flap being fed by air tapped from the compressor.

Hawker (Siddeley) P.1152

This V/STOL strike fighter appears to have been examined in a little more depth than P.1151 and P.1153. Four RB.162 lift jets with aft vectoring nozzles were individually placed near the four corners of the wing roots and a single reheated clang-box RB.177 cruise engine with deflected vectorable exhaust was used for hover lift. The RB.177 had two vectoring nozzles under the wing and a tail jet pipe with a variable area reheat nozzle. A high variable incidence wing was employed with three-piece leading-edge flaps, plain flaps, two-piece ailerons and two-piece outboard spoilers. A low-position all-moving slab tail was fitted, each leg of the tricycle undercarriage had two wheels and the lower rear fuselage carried an underfin with a tail hook. Three tandem pairs of semi-submerged 1,000lb (454kg) bombs were carried along the underfuselage inside the line of the RB.162s.



Hawker (Siddeley) P.1152 (mid-1961). Brooklands Museum

Hawker (Siddeley) P.1153

This large supersonic strike aircraft to OR.346 had one reheated BS Olympus 22R in a ventral housing beneath the forward fuselage and fed by a chin intake. It also had deflected thrust activated by a cascade deflector with two vanes which slid down behind the jet pipe orifice, plus a rotating vane at the bottom of the jet pipe. This was a brief study only.

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With the arrival of the NBMR.3 competition (see Chapter 10), the Admiralty was directed by the Government to investigate the prospects for agreeing to a common version of the aircraft to cover both RAF and RN requirements. The Navy rejected this in February 1962, despite showing interest in P.1154, because the requirement's range and weapon-carrying capability were inadequate, while the problems of low-altitude strike and all-weather interception demanded a crew of two (NBMR.3 was a single-seater). Also, giving the NBMR.3 an adequate interceptor capability would make it so similar to the OR.346 fighter mode that its additional and separate development was not justified. However, after the P.1154 'won' NBMR.3, the Navy had to take a version of it, which brought an end to its ambitions for an OR.346 type aircraft. None of the studies in this chapter were turned into real aeroplanes, but they did lay much of the groundwork for Tornado.

OR.346 Multi-Role Projects – Estimated Data

Hawker Siddeley Group

Project	Span ft in (m)	Length ft in (m)	Wing Area ft (m)	t c %	All-Up-Weight lb (kg)	Powerplant Thrust lb (kN)	Max Speed Height mph (km h) ft (m)	Weapon Load lb (kg)
Blackburn B.123 (7 61, T-tail)	37 0 (11 3)	81 0 (24 7)	550 (51.2)	5	56,500 (25,628) (max. deck weight with 2,000lb nuclear bomb)	2 x Spey reheated	(Clean) Mach 2+ at height	Strike. 1 x 2,000 (907) nuclear weapon, 6 x 1,000 (454), Bullpup; Interceptor AAMs
Blackburn B.123 (61, low tail)	40 0 (12.2)	73 9 (22 5)	600 (55.8)	5	61,380 (27,842) (naval strike or AAMs)	2 x RB.168-1R 15,000 (66.7), 25,500 (113 3) reheat and 2 x RB.162 lift 5,000 (22 2)	(Clean) Mach 1 4 at sea level, Mach 2 5+ at 36,000 (10,973)	Strike. 1 x 2,000 (907) nuclear weapon, 6 x 1,000 (454) 5 Bullpup, 3 x RG.10 ASMs; Interceptor: AAMs
de Havilland DH.127	33 0 (10 1)	60 0 (18 3)	560 (52 1)	5	49,100 (22,272) (std to OR 346), 56,000 (25,402) (overload)	2 x RB.156-1R 11,065 (49 2), 18,650 (82 9) reheat and 2 x RB.162 lift 4,400 (19.6)	Mach 2.5 at height	Strike. 1 x 2,000 (907) TMB, 8 x 1,000 (454), 4 Bullpup or RG.10s; Interceptor 4 x Red Top AAMs
Hawker P.1152	45 0 (13 7) (RAF) 40 0 (12 2) (RN)	68 6 (20 9)	?	?	50,000 (22,680)?	1 x RB.177 lift cruise engine, 4 x RB.162 lift engines	Mach 2	Strike. Includes 1 nuclear weapon, 6 x 1,000 (454). Interceptor AAMs

Project	Span ft in (m)	Length ft in (m)	Wing Area ft² (m²)	t/c %	All-Up-Weight lb (kg)	Powerplant Thrust lb (kN)	Max Speed Height mph (km/h) ft (m)	Weapon Load lb (kg)
Swallow (OR.339)	117 5 (35.8) forward, 30 8 (9.4) swept	77 0 (23.5) forward, 95 7 (29 1) swept	537 (49.9) forward, 900 (83.7) swept	13.1 forward, 3.6 swept	50,000 (22,680), 33,000 (14,969) as research aircraft	4 x BE 38 Orpheus	Supersonic at height	Red Beard, 5 x 1,000 (454), 74 x 2in RPs or 12 x 3in RPs
ER.206/1 (TSR.2 Developments)								
Scheme A	41 0 (12 5) with tip tanks	66 7 (20 3)	284 (26.4) without tanks	5	All: 48,800 (22,136) in strike role, 48,000 (21,773) as interceptor	All: 2 x RB.142 4 8,000 (35 6), 13,000 (57 8) reheat	All: Mach 2+ at altitude	All. Strike, Red Beard, 6 x 1,000 (454) or 2 Bullpup internal, Bullpup, RPs or bombs under wings. Interceptor: 2 x 750 (340) AAMs internal
Scheme B	43 8 (13.3) with tip tanks	66 7 (20.3)	400 (37.2) without tanks	5				
Scheme C	28 3 (8.6)	66 7 (20.3)	410 (38.1)	3 6				
ER.206/2 (10.59)	57 6 (17 5) forward, 31 0 (9.5) swept	76 4 (23.3)	554 (51 5) forward, 552 (51 4) swept	11.5 forward, 4 19 swept	Strike: 50,000 (22,680), Interceptor: 48,000 (21,773)	4 x RB 153 + 2 lift engines	Mach 3.0 between 43,000 (13,106) and 70,000 (21,336)	Strike: Red Beard, 6 x 1,000 (454), 3 Bullpup, 2in or 3in RP packs; Interceptor: 3 x 600 (272) AAMs
ER.206/3 (3.60)	58 0 (17.7) forward, 31 0 (9.5) swept	71 6 (21 8)	528 (49 1) forward, 526 (49.0) swept	4.1 swept	Strike: (4 x 1,000lb load) 45,114 (20,464), Interceptor: 44,574 (20,219)	2 x 0.7 scale RB.163 7,740 (34.4), 13,480 (59 9) reheat	Mach 2.5 between 60,000 (18,288) and 75,000 (22,860)	Strike: 1 x 2,000 (907) TMB, 6 x 1,000 (454), or 3 Bullpup. Interceptor: 4 x AAMs
ER.206/4 (5.60)	59 10 (18.3) forward, 32 6 (9 9) swept	66 1 (20 1)	430 (40.0) forward, 600 (55.8) swept	11.5 forward, 4.1 swept	47,850 (21,705)	2 x RB.165 8,850 (39 3), 15,400 (68 4) reheat	Mach 2.5 at height	Strike. 1 x 2,000 (907) TMB, 6 x 1,000 (454), or 3 Bullpup; Interceptor: 4 x AAMs
Type 582 (twin fuselage)	45 0 (13.7) tip AAMs, 40 0 (12.2) without	65 4 (19 9)	405 (37.7)	12.6 in centre section	Strike: 46,230 (20,970)	Both: 8 x scaled RB.163 1,800 (8.0) dry	Mach 2 at height (Interceptor: Mach 2.5)	Both: Strike. 1 tactical atomic weapon, 6 x 1,000 (454), 4 Bullpup. Interceptor: 4 x AAMs
(single fuselage)	45 0 (13.7) tip AAMs, 40 0 (12.2) without	65 8 (20.0)	408 (37.9)	12.6 in centre section	46,087 (20,905)		Mach 2(?)	
Type 585	46 8 (14.2) forward, 24 8 (7.5) swept	58 4 (17.8)	300 (27.9) forward	not given	26,000 (11,974) (take-off weight)	1 x Avon with reheat	Mach 2.2 at height	?
Type 589 (research aircraft)	49 9 (15.2) forward, 27 6 (8.4) swept	64 3 (19 6)	355 (33.0) forward	not given	48,900 (22,181) (normal take-off)	2 x RB.146 Avon reheated	Mach 2 2 above 38,000 (11,582)	None

Vertical Take-Off

View of XS688, the first Hawker Siddeley 'P.1127' Kestrel FGA Mk.1.

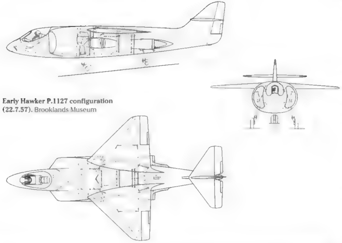
Harrier and NBMR.3: 1957 to 1985

Hawker Aircraft at Kingston will be forever remembered for the World War Two Hurricane, the beautiful Hunter jet fighter and the Harrier vertical take-off and landing (VTOL) attack aircraft. That VTOL capability makes Harrier one of the most remarkable aircraft to have been produced anywhere in the world and, 40 years after first flight, it remains the only example of its type in service, having racked up an impressive record of action in both the Falklands and Gulf campaigns. Many developments and variants were proposed, either privately or to official requirements, before the Kingston factory closed in 1992.

Hawker P.1127

The concept of a combined lift/thrust engine, based on the principle of vectored thrust, emerged in 1956 as a result of studies by Bristol Aero Engines and the subsequent co-operation between Bristol and Hawker resulted in the P.1127 of 1957. Hawker's interest in developing a VTOL aircraft using this novel engine, the BE.53 (Pegasus), came to the fore in the middle of June 1957 as a private venture. The company's P.1121 supersonic strike fighter had been declared unacceptable for the RAF on 30th May and designer Sydney Camm knew his team needed more work.

BE.53 was essentially a ducted fan driven by the free turbine stage of a conventional gas turbine. The fan air was collected into ducts which were rotated to direct the jet rearwards or downwards; by August 1957, the fan gave an estimated sea level static thrust of 7,350lb (32.7kN) and the turbine exhaust another 4,000lb (17.8kN). In early P.1127 studies it was assumed that the hot jet gases would not be deflected but instead the aircraft would sit nose-up at a high angle when hovering so that approximately half of the BE.53's thrust was available as lift. The fan nozzles were directed slightly forward of vertical so that the horizontal components of fan and jet were cancelled out. In this configuration, however, VTO was not possible with a useful military load and other methods of hot gas deflection were investigated. Eventually the jet outlet



Early Hawker P.1127 configuration (22.7.57). Brooklands Museum

The first P.1127 prototype XP831.

The second prototype P.1127 XP836 reveals the rotatable nozzle and bicycle undercarriage arrangement of this revolutionary aircraft. Brooklands Museum

was bifurcated behind the turbine in the manner employed on the Sea Hawk fighter and ducted to nozzles on either side of the fuselage so that deflection was accomplished by nozzle rotation in the form still used today.

P.1127 was finalised in August 1957 as a single-seat subsonic strike and reconnaissance aircraft and presented to Supreme Headquarters Allied Powers in Europe (SHAPE). The brochure showed a very basic aircraft which could take off vertically in 'clean' condition with full fuel (270gal [1,228lit] in a single wing tank) or lift off with 2,000lb (907kg) of external stores after a ground run of only 600ft (183m). It could be regarded as a minimum airframe, capable of VTO for short-range duties and able to lift off with a range of external stores from any main road or average-size field; in addition this was achieved without sacrificing a high subsonic top speed of Mach 0.94. The duties envisaged for P.1127 did not need transonic speeds so the flying surfaces were only moderately swept. All of its weapons or two 100gal (455lit) drop tanks were carried externally and sea level rate of climb at half fuel weight (7,500lb [3,402kg]) was 35,300ft/min (10,759m/min).

During the September Farnborough Show SHAPE's Col Chapman visited Hawker and commented favourably on the design, but he suggested that the radius should be doubled to around 250nm (463km) and that VTO was not necessary at higher weights, especially when carrying a nuclear weapon. By month's end P.1127 had been altered to carry a 2,000lb (907kg) atomic weapon under the fuselage. The design was generally similar but for a bigger span (24ft [7.3m]), internal fuel increased to 500gal (2,273lit) and the addition of water-methanol injection to the BE.53 which increased total thrust to 13,000lb (57.8kN); this allowed a VTO at 10,250lb (4,649kg). In the absence of any firm requirement leading to a specialist role for P.1127, Hawker's aim had been to provide the most generally useful airframe that could take advantage of the new possibilities opened up by direct lift.

This new brochure was delivered to SHAPE Headquarters in Paris on 8th October 1957 by Hawker Managing Director Frank Spriggs, Chief Designer Sydney Camm, Ralph Hooper (P.1127 Project Engineer responsible for the aircraft's design) and Bob Marsh (Head of the Project Office). Great interest was shown and

whilst performance and range appeared to be of the right order, it was considered that more equipment was needed including radar ranging for ground attack and a form of Doppler navigation. The recently completed NATO light fighter' competition won by the Fiat G91 (Chapter 12) had shown that the competing aircraft suffered severely through a lack of such equipment. Hawker asked SHAPE for some financial support because none was forthcoming from the MoS, although the Controller Aircraft had praised the design.

In January 1958 it was confirmed that American MWDP support would be available for the BE.53 and that NATO interest in a VTO tactical fighter was growing. For P.1127 the emphasis moved back to VTO and ultra-short take-off at the expense of equipment and within a month Hawker finalised two approaches – one virtually the existing P.1127 with a nuclear weapon and moderately sophisticated electronics, the other reduced in size and carrying underwing RPs and minimal military equipment. On 11th March Sir Thomas Pike, Head of Fighter Command, saw the P.1127 and was much impressed. A few days later Wg Cdr Nelson Edwards from Operational Requirements also showed great interest but expressed the opinion that in order for it to receive any serious consideration, P.1127 should have supersonic interception in addition to its strike capabilities.

A full-scale meeting at Hawker on 5th August included General Boyd and John Stack of NACA, Col Chapman and Col Klein from MWDP, Sir Arnold Hall (Hawker Siddeley Group Technical Director) and all of the company's Directors. The Americans were very impressed with the design and its progress (they were also interested in the P.1121 strike fighter which they considered was a better proposition for the RAF to consider now rather than OR.339 in some five years time). Seven weeks later Camm was told by Air Marshal Sir Geoffrey Tuttle, DCAS, that the Air Ministry was considering 'target' requirements for a VTO transport and a light fighter and in January 1959, thanks to increasing Air Staff interest, the MoS began to consider ordering two prototype P.1127s. The Air Staff, having 'triumphed' on OR.339, felt freer to take an active interest in other projects and they intended to ask for a P.1127 type to replace Hunters in the tactical ground support role. However, no MWDP money was available because the Vickers Swallow had used up all of its funds for the last financial period.

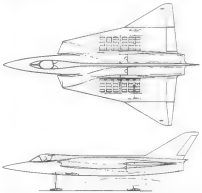
On 27th November 1959 the Minister of Aviation Duncan Sandys, the architect of the 1957 Defence White Paper and its 'no more manned fighter' policy, visited Kingston to learn about P.1127. He was treated to a full presentation but the Hawker diary notes that he 'generally did not appear to be very receptive'. There were opponents to the P.1127 concept, including a Wg Cdr Chamberlain who often displayed a critical and discouraging pose; on one occasion Hawker's representatives noted that he and Gp Capt T Witt had both received 'the anti-P.1127 treatment from Rolls-Royce'. Rolls preferred the individual lift jet concept and that company's Adrian Lombard and Ronnie Harker visited Kingston in March 1960 to discuss an alternative VTO powerplant for a P.1127 type, but Hawker told them that the separate lifting engine technique gave no weight advantage over a single lift thrust powerplant.

During 1959 the MoA issued a contract for the development and manufacture of two P.1127s for research into V/STOL operations; up to now the aircraft had been a private venture. At the same time the Air Staff thought P.1127 would be suitable for 'Colonial Policing' and, under MoA pressure, issued a draft Staff Requirement in February for a tactical ground attack fighter. In June 1960 this was officially issued as GOR.345, with Specification ER.204D, for a short-range V/STOL ground attack recce aircraft for close support in a limited war. The first prototype, XP831, made its initial hovering flight on 21st October 1960, four more prototypes were ordered in November, XP831 made its first conventional flight on 13th March 1961 and full transitions from vertical to horizontal flight and back were completed on 12th September.

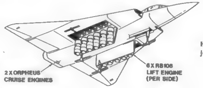
During the early stages of VTO research, Hawker examined several alternative designs and engine arrangements which included:

Hawker P.1126

This double-delta strike aircraft with 12 Rolls RB.108 lift jets and twin Bristol propulsion units was a very early VTOL project. To reduce storage volume and drag the 'pop-out' the RB.108s retracted outwards to lie sideways in the inner wing, the increase in powerplant weight being offset by the adoption of a light helicopter-type skid undercarriage with very small wheels (P.1126 had no STOL capability). Using two separate banks of lift engines avoided the suck-down problem experienced in types such as the Short S.C.1, while the jet 'fountain' created at the fuselage centreline gave a positive cushion near the ground. Span was 32ft (9.75m), length 53ft (16.2m), wing area 640ft² (59.5m²), fuel capacity 740gal (3,365lit) and only strike weapons were carried. P.1127 was an altogether simpler and cheaper approach.



Hawker P.1126 (6.57). Brooklands Museum

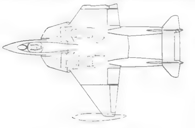


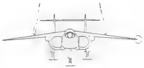
Hawker P.1126 with its 12 RB.108 lift jets deployed.

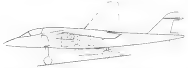
Hawker P.1132

A subsonic VTOL strike aircraft for tactical duties over land and sea. It had twin BE.53s housed side-by-side in the fuselage, a large centre fuselage and intakes and a delta wing. P.1132 (18th April 1958) had twin booms, tip tanks, a single forward nozzle on each side and rear nozzles turned inwards to the rear of the centre fuselage. Its span was 37ft (11.3m), length 48ft 6in (14.8m), wing area 400ft² (37.2m²) and 1,200gal (5,456lit) of internal fuel was carried. P.1132-1 (April 1958) had a P.1127-style tail unit, Napier Double Scorpion rocket motor and four side nozzles (two from each engine), with the BE.53s angled inwards towards the rear to make room for the rear nozzles. Span was 37ft (11.3m), length 49ft 6in (15.1m), wing area 400ft² (37.2m²) and internal fuel 1,000gal (4,547lit).

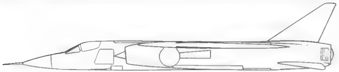
Engine-out asymmetry would have been a problem with these designs because the lack of crossover ducting between the BE.53s would create a rolling moment; the only response to the loss of thrust when hovering, and the consequent rapid downward acceleration, would be immediate ejection. After an engine failure the twin-boom P.1132 would have three-quarters of its remaining thrust close to the centreline but, much worse, the single fuselage type would have half of the remaining thrust well offset.

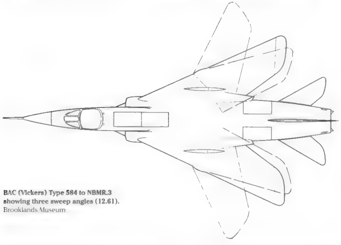






The twin-boom version of the Hawker P.1132 (18.4.58). Brooklands Museum





BAC (Vickers) Type 584 to NBMR.3 showing three sweep angles (12.61). Brooklands Museum

NBMR.3

In August 1961 the Air Ministry reported that the subsonic P.1127 would not meet its needs but it was prepared to take up to 30 aircraft if that would help a foreign sale; they could also provide a constructive 'lead-in' to later supersonic versions. For its Hunter replacement the Air Staff really wanted a supersonic type such as the Dassault Mirage IIIV. This policy was officially stated in November and the MoD was tasked to submit proposals for developing a supersonic close support aircraft that took both Navy and Air Force requirements into consideration. The result was Hawker's supersonic P.1150 with plenum chamber burning (PCB) but General Chapman felt this aircraft was too pedestrian and not large enough for a new SHAPE requirement that had also appeared.

That document was NATO Basic Military Requirement 3 (NBMR.3) for an all-weather supersonic VTO strike, reconnaissance and tactical support aircraft which was circulated to European industry in June 1961; designs were to be submitted by year's end. Project NBMR.3 was to consist of two phases: the first would cover further development and testing of the P.1127; the second would see production of a supersonic aircraft capable of speeds above Mach 1, even possibly at ground level. It would be able to deliver 2,000lb (907kg) of stores, including nuclear, over a 250nm (463km) radius of action and fly at a minimum Mach 0.92 at sea level with its medium-altitude speed as high as possible. Operating altitude would be between 500ft (152m) and 40,000ft (12,192m).

Service entry was expected four years after the selected prototype first flew. Eleven designs were tendered to NBMR.3 including three all-British projects and the Breguet Br.1115, Dassault Mirage IIIV (with Sud and Rolls-Royce), Fiat G.95/6, Focke Wulf FW.1262, Fokker/Republic D.24 Alliance, Lockheed, Short CL-704 and Nord 4210. BAC (EE) Warton also became involved in Mirage IIIV development and that company's P.39 project was basically an anglicised IIIV. In February 1963 a P.39 variant was proposed as an all-weather interceptor/strike/recce aircraft for the Royal Navy with two RB.153-61C cruise engines and two RB.162 lift units. British NBMR.3 contenders were as follows:

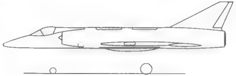
Two views of the Type 584 model. BAE Systems

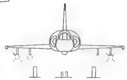
BAC (Vickers) Type 584

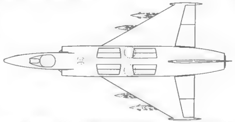
This drew on Vickers' TSR.2 and VG experience and its comprehensive range of equipment would enable the single crewman to carry out tactical duties under any weather conditions. BAC's accumulated experience with the Swift and Scimitar in high-speed low-level flight, and high supersonic speed with the Lightning, formed the background to the project. Furthermore, during the design and development of TSR.2 the company had made further intensive studies of high-speed low-level flight and high supersonic performance at medium and high level, all combined with advanced all-weather attack/navigation systems.

Type 584 could deliver a 1,250lb (567kg) nuclear bomb on a target 300nm (556km) from base, reconnaissance information being acquired on the same sortie by high-definition sideways-looking radar. Its variable sweep mainplane reduced gust response and minimum subsonic drag while the overall dimensions were probably the smallest that could fully meet NBMR.3. A single RB.177 bypass engine (known in May 1962 as the Medway) supplied propulsive thrust while eight RB.162 lift jets were located in two groups, one forward between the RB.177's intakes, the other aft alongside its jet pipe. On take-off, the fuselage was inclined 15° nose up so that the thrust's vertical component augmented the lift; a device for spoiling or reversing the propulsive thrust was located in the fuselage tail cone. BAC reported that using separate engines offered rapid acceleration, and thus a short transition time, while keeping frontal area to a minimum.

Two weapon bays were located either side of the lower centre fuselage while the terrain-following radar and target ranging were in the nose. The 584 had wing tip ailerons, an all-moving tail but no leading-edge or trailing-edge flaps; during the VTOL phase, control was supplied by jet reaction nozzles fed with air bled from the lift and propulsion engines. These nozzles were coupled with the aerodynamic control surfaces which became fully effective by the time wingborne flight was achieved. If an ITP was received in early 1963, Type 584 would enter service in mid-1968. Both RN and RAF variants were proposed but work on the project stopped on 29th June 1962 once the design was rejected. Rolls-Royce noted that the Type 584 had a greater capability than the Mirage IIIV.



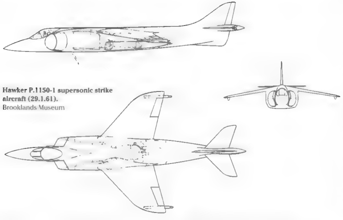




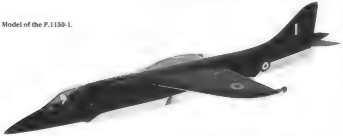
Short P.D.56 to NBMR.3 (1961).

Short P.D.56

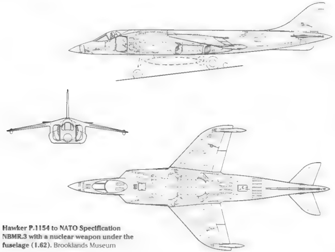
This was designed for low-level tactical strike and reconnaissance with high-speed interception as a secondary role. A bank of four RB.162 lift units was placed either side of the centre fuselage, elevons were installed along the delta wing's trailing edge and conventional power was supplied by a single RB.168. Shorts felt that multiple lifting engines provided the maximum degree of safety in jet-borne flight and P.D.56 could continue its take-off transition, complete its mission and return to base even after a total failure of one lift engine at any point in the take-off. Radius of action with a 1,000lb (454kg) load flown at low-level was 280nm (519km), at medium altitude and subsonic speed this became 540nm (1,000km) and with a supersonic dash from half distance 220nm (407km). Internal fuel totalled 7,750lb (3,515kg) and ceiling was over 50,000ft (15,240m).



Hawker P.1150-1 supersonic strike aircraft (29.1.61). Brooklands Museum



Model of the P.1150-1.



Hawker P.1154 to NATO Specification NBMR.3 with a nuclear weapon under the fuselage (1.62). Brooklands Museum

Hawker (Siddeley) P.1150-1

The companion *British Secret Projects: Fighters* also describes the P.1154's 'career' but a version was proposed to the NATO specification (the overlap between fighter and bomber is never closer than in this particular story). However, Hawker's supersonic P.1150-1 of January 1961, powered by a BE.53-6 with 800°K PCB, was the company's first suggestion to NBMR.3. (Plenum Chamber Burning, PCB, incorporated fuel burning in the normally unheated cold bypass airstream to the front nozzles.) It had a span of 26ft (7.9m), length 53ft (16.2m), wing area 244ft² (22.7m²) and internal fuel load of 850gal (3,865lit). When the requirements were upgraded, P.1150-1 became too small and a modified version called P.1150-3 was drawn which was redesignated P.1154. Hawker's full NBMR.3 P.1154 submission was delivered to the MoA on 8th January 1962 for transmission to NATO.

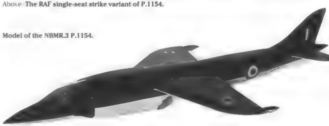
Hawker (Siddeley) P.1154

Hawker described the NBMR.3 P.1154 as a second generation V/STOL fighter and the natural supersonic development of the P.1127. It used an enlarged BE.53 type lift/thrust engine, the Bristol BS.100/9, with PCB; from a VTO this offered a larger military payload for the high-speed low-level strike mission and Mach 2.0 performance at altitude. BS.100/9 was a scaled down version of the BS.100/3 considered by Fokker/Republic and Breguet in their NBMR.3 designs. This gave 17% less thrust but a performance which still exceeded NBMR.3. Hawker noted that what NBMR.3 really requested was an aircraft which combined the airfield performance of a helicopter with the combat performance of the latest supersonic fighters and that a speed range of this order of magnitude had not previously been attempted even by a research aircraft, let alone a fully operational weapon system.

During the preliminary design study phase Hawker considered many different configurations and powerplant combinations but concluded that the single-engined lift/thrust concept demonstrated by the P.1127 was the type that most completely met NBMR.3. Other powerplants such as multiple lift engines along with a separate propulsive unit might offer slight advantages in certain specialised areas but they failed in the overriding case of providing a practical operational system. The experience gained from flying the P.1127 put Hawker Siddeley in a unique position in that no other high-performance aircraft had undertaken transitions from both vertical and short take-off, and this with a representative military aircraft.

For NBMR.3 the P.1154 had a lightweight forward-looking radar which formed the basis of a simple automatic system for terrain-following and blind approach to a vertical landing, as well as for target ranging in attack. One nuclear weapon or two 1,000lb (454kg) bombs could be carried under the fuselage and ASMs, AAMs, more 1,000lb bombs or RPs loaded onto four underwing pylons. A nose camera or special pods under the fuselage were used for reconnaissance, internal fuel totalled 1,150gal (5,229lit) and normal weapon load 2,000lb (907kg). With a pitot intake, P.1154 had a maximum speed at altitude of Mach 2.0 and a radius of action in the primary low-altitude mission of 295nm (545km); an alternative variable-wedge intake offered Mach 2.4 and 265nm (491km); airspeed design limit was 864mph (1,390km/h) IAS and Mach 2.3. From ITP it was estimated that a squadron of 12 aircraft could be produced within four years and subsequent production rates would fully meet NATO requirements.

Above **The RAF single-seat strike variant of P.1154.**



Model of the NBMR.3 P.1154.

Hawker (Siddeley) P.1155

This was a three-engine NBMR.3 alternative to P.1154. It originated from a February 1962 request by DGSR for Hawker to investigate using the existing Pegasus, augmented by separate lift units, instead of the BS.100 should that engine's development not proceed (there were doubts concerning BS.100 availability due to its development costs). P.1155 was first presented to DGSR on 24th April and it was substantially the same airframe as P.1154, having begun life as the P.1150-2. The big difference was the BE.53 Pegasus 5 with PCB and two RB.162 lift units, one behind the cockpit between the intakes and one behind the main undercarriage bay; intake doors were visible on the upper fuselage. On 6th December 1961 the Defence Committee had authorised the official consideration of a supersonic development of the P.1127 and this was the type of aircraft it had in mind, the MoA regarding it as a most promising development. The powerplant arrangement, however, did not find favour with the Ministry's Technical Branch but it was financially more acceptable since the engines themselves were already being funded. Internal fuel totalled 1,150gal (5,229lit) and the nuclear weapon was still carried beneath the fuselage.

Hawker concluded that the P.1155 would have about 20 miles (32km) less radius of action than P.1154 after a VTO and about 40 miles (64km) less with the aircraft loaded to clear a height of 50ft (15.2m) after a 500ft (152m) take-off run. Total weights for the two types were substantially the same but P.1155's top speed was about Mach 0.1 less at 36,000ft (10,973m). Because of its greater propulsive thrust P.1154 would, in getting up to high speeds, have about 50% more acceleration and Hawker expressed strong opinions against the three-engined concept on the grounds of safety, complexity, ground erosion and debris ingestion problems.

The Ministry acknowledged that any engine failure in a three-engine type during a large part of its take-off manoeuvre was likely to lead to a major accident because of the loss of a substantial portion of its thrust. Additionally, if a lift engine failed, unless the other lift unit was cut very quickly (presumably by automatic devices) then very rapid changes in pitch would take place. This suggested that the three-engined aircraft was not as safe as the single-engined version though in any situation other than take-off the loss of the propulsion engine was as likely as in the P.1154. It was felt that the P.1155 was the ideal technical solution for a supersonic P.1127, but these studies had also revealed serious operational and logistical drawbacks. The idea was not attractive to the Services and P.1155 was therefore not submitted to NBMR.3.

By late April 1962, five NBMR.3 submissions were still in the running but the Short P.D.56 solution was one of those eliminated. The NATO assessment body felt the BAC 584 was attractive technically but it was heavier, more complex, more expensive and later in timescale than envisaged for NBMR.3 so, consequently, it too would be rejected. The Fokker/Republic project was likely to be ruled out and the Breguet design was not expected to win. P.1154, a private venture from Hawker, and the Mirage IIIV stood a good chance of winning and in addition there was a desire by the Ministry to put UK requirements in line with NBMR.3, although they were not identical.

The Air Staff felt that NBMR.3 could result in a decision that P.1154 was the winner or – more likely – the winner in all but French eyes, but the Mirage's prospects had improved because that programme was

going full speed ahead with official support while P.1154's airframe had no such backing and the engine only limited financial assistance. Consequently there was some debate as to whether the British would buy the Mirage IIIV if it was declared the winner when it was believed that no non-British aircraft could meet both Services' needs.

It seemed vital to preserve Britain's freedom of action in these activities and one solution was, if P.1154 did not become the undisputed winner, that there should be no undisputed winner. That meant, if necessary, entering a minority report on behalf of P.1154 and seeking to make that minority greater than one by getting support from other nations. For example the Italians 'owed us a favour for our help with the Fiat G.95/6'. It was agreed in April 1962 that the P.1154's engine and airframe development should now receive full and immediate Government support to maintain its competitive position in NBMR.3. Eventually P.1154 was adjudged the technical winner, but France announced it intended to pursue the Mirage IIIV. Such national considerations, plus technical unknowns stemming from the need to combine VTO and supersonic capability, made it virtually impossible to solve this dispute and so NATO's requirement was withdrawn in autumn 1962. NBMR.3 had been very political and perhaps Europe was not quite ready for it.

In January 1962 the first draft of NASR-(OR).356 was issued in place of GOR.345 and this eventually covered the P.1154 after it was chosen to join both the RAF and RN. It was amended to a two-stage development in November, a single-seat V/STOL strike/recce aircraft for the RAF by 1968 (P.1154A) and a two-seat all-weather version, primarily a fighter, for the Navy by 1970 (P.1154B). Specification F.242 covered the requirement but was later replaced by SR.250D first drafted in July 1964. As development proceeded it was found that the required level of 'commonality' compromised each Service's aircraft and accordingly the specification was revised to give more scope to specialised designs for each role. Gradually the two versions grew apart and in February 1964 the Royal Navy was allowed to buy the McDonnell F-4 Phantom from America. Just the RAF P.1154 was ordered, only to be cancelled in February 1965 for economic reasons.

Hawker Siddeley Kestrel

During the 'P.1154' period the P.1127 kept a relatively low profile though the prototypes flew well. In February 1963, after a full year of discussions, a joint agreement was reached between Britain, West Germany and the United States to build nine improved aircraft for service evaluation of the V/STOL concept. The first aircraft, XS688 built to Specification FGA.236D & P, made its first flight on 7th March 1964 and in July the name Kestrel FGA Mk.1 was accepted by the Air Staff, appropriate since 'this was a hovering Hawk Falcon type bird'. The Tripartite Kestrel Evaluation Squadron (RAF, USAF, USN, US Army and Luftwaffe) undertook an assessment through the first half of 1965 and proved a total success with the RAF in particular pleased with the results. The Kestrel was the first jet V/STOL aircraft in the world to be granted a release for use by service pilots.

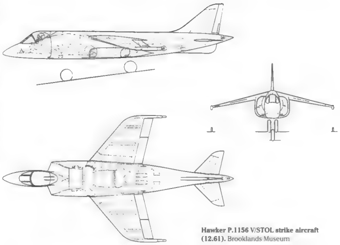
Hawker Siddeley Harrier

By January 1965, with the end of the P.1154 in sight, there was considerable activity in Kingston's Project Office for a proposed P.1127 Development. The Ministry decided that, since V/STOL and supersonic performance could not be found together in any other aircraft, the tasks required of the Hunter replacement should be met by a mix of Phantoms and a developed version of the Tripartite Kestrel. Discussions suggested that if the P.1127 was fitted with more a powerful engine and with the equipment proposed for the P.1154 (except for the radar), in the strike role its performance would not be greatly inferior to P.1154's. Thus, in the low-level strike role the P.1127 could be regarded as a reasonable substitute. Draft ASR.384 was circulated the following month for an operational aircraft to be called the P.1127(RAF) and this was covered by Specification SR.255D & P. Twelve months of project definition and preliminary design study began on 1st April.

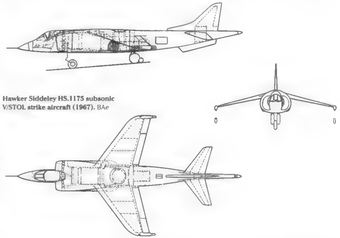
XV277 was the second Harrier GR Mk.1 Development aircraft.

The initial brochure noted that changes from the Kestrel would include a Pegasus 6, comprehensive military equipment and a stronger undercarriage and structure. On 8th July Wg Cdr Bairsto informed Kingston 'He would like to place on record how pleased MoD were that the company were able to go so far towards meeting the exacting ASR, starting from an existing aircraft'. The main arguments against P.1127(RAF) were a poor VTOL weapon load (1,000lb [454kg]) and low cost-effectiveness in the VTOL mode when compared with the Phantom and Buccaneer (both incapable of VTO). In its favour, the type would keep Britain in the forefront of V/STOL technology, it could operate intimately with the Army and off almost any available site, would give a rapid response capability and could often be used in the STOL mode with a greater weapon load. It would also be capable of further development (a P.1127 with PCB was proposed in June 1966).

Full development was authorised on 9th March 1966 and on 22nd December the Cabinet decided to place a firm order for 60 aircraft. Names suggested earlier for the P.1154 were Falcon, Peregrine and Harrier, favoured in that order, but the production P.1127 was allocated Harrier on 17th March 1967. The first of six development aircraft, XV276, flew on 31st August 1966 and the first production Harrier GR Mk.1, XV738, became airborne on 28th December 1967. Deliveries of 78 Mk.1s to the RAF began in April 1969 and most were later upgraded to GR Mk.3 standard with the uprated Pegasus 11 and LRMTS. Harrier's primary role was close air support and it has proved an immense success with the RAF and US Marine Corps (as the AV-8A).



Hawker P.1156 V/STOL strike aircraft (12.61). Brooklands Museum



Hawker Siddeley HS.1175 subsonic V/STOL strike aircraft (1967). BAe

Hawker (Siddeley) P.1156

Over the years, Kingston produced numerous Harrier development proposals and P.1156 was a V/STOL strike fighter similar to the P.1127 powered by a Pegasus 5 with anhedral multi-vane nozzles like the P.1154, which allowed the engine to be removed with the wing still in place. Its span was 23ft 4in (7.1m), length 42ft 0in (12.8m), wing area 186.4ft² (17.3m²) and internal fuel capacity 600gal (2,728lit).

Hawker (Siddeley) HS.1175

Hawker Siddeley Kingston invented, developed and proved the single-engine vectored thrust fighter-attack configuration but the company was never complacent about it. Harrier had faults and weaknesses and the Kingston design team (and later Warton when the companies merged as part of British Aerospace) strove constantly to find alternative solutions. Other V/STOL and STOVL configurations showed advantages but they proved inadequate when judged against the four-nozzle vectored thrust format. (Author's note – From about HS.1170 onwards, any future project studies could embrace many different layouts.)

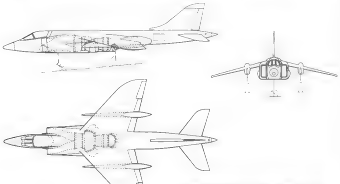
HS.1175 was privately proposed in 1967 as a second-generation V/STOL subsonic strike aircraft with much structure and systems in common with Harrier, but the Pegasus was recased in a two-nozzle arrangement and supplemented by a single vertically mounted

Rolls-Royce-Allison XJ.99 lift jet (an Anglo-American engine developed jointly under the US/UK Advanced Lift Jet Engine Demonstrator Programme which, at the time, had no production application but had been bench tested). The extra VTO thrust and a new large-span wing with three pylons per side enabled much greater weapon loads to be taken on VTOL missions.

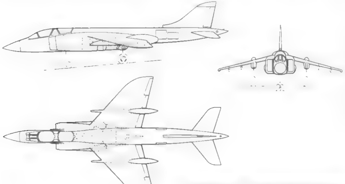
HS.1175's timing was flexible and dependent upon the progress of Harrier developments; most funded Harrier improvements (Pegasus thrust increases, improved systems, etc.) could be used on HS.1175 which would follow on naturally as Harrier's development tailed off. Low-level radius of action from a VTO with full internal fuel (875gal [3,979lit]) and 3,000lb (1,361kg) of weapons was 225nm (417km) while an 800ft (244m) ground run plus two 200gal (909lit) external tanks pushed this up to 310nm (574km); high-level flight with low level over the target increased these to 460nm and 600nm (852km and 1,111km) respectively. Maximum VTO weight was 24,500lb (11,113kg) and Mach number limit 1.30. Work had ceased on the HS.1175 by April 1969.

Hawker (Siddeley) HS.1176

In its basic version this was externally similar to the Harrier but had its intake area enlarged by some 10% to accept the greater airflow of the 24,500lb (108.9kN) Pegasus 9D. It was proposed in partnership with Allied Systems to the US Department of Defense for possible use by the USAF as a rapid response strike aircraft. It also formed the basis of a joint UK/USA cost-effectiveness study in which V/STOL strike aircraft (typified by the HS.1176) were compared with current and future conventional strike aircraft. Strengthened pylons offered an external weapon load of 6,000lb (2,722kg); at overload this rose to 10,000lb (4,536kg) for a maximum take-off weight of 27,300lb (12,383kg). More advanced versions were suggested.



Hawker Siddeley HS.1179L single-seat V/STOL strike aircraft (mid-1968). Brooklands Museum



Hawker Siddeley HS.1179M two-seat V/STOL strike aircraft (mid-1968). Brooklands Museum

Hawker (Siddeley) HS.1179

This designation covered a substantial private venture study by HSA Kingston and Brough which embraced over 20 strike fighter projects. They were aimed at the requirements for the MRCA (see Chapter 14) currently being drafted for the RAF, Dutch, Italian and German Air Forces as a UK and European Advanced Combat Aircraft, with a prospective market of around 800 aeroplanes. In general, vectored thrust designs were investigated by Kingston (HS.1179A to M) and projects using VG or boundary layer control by Brough (HS.1179S to Z). Recent work at both sites had concentrated on a vectored thrust layout using a Pegasus 9D-03, a PCB derivative of the unit proposed for the HS.1176.

Kingston's HS.1179 studies included RB.199 engines. The HS.1179E had twin reheated RB.199s and PCB in the side nozzles, the single-seat HS.1179H used a single reheated RB.199 with PCB; span was 30ft 6in (9.3m), length 51ft 0in (15.5m) and wing area 300ft² (27.9m²). HS.1179J was a bigger two-seat twin RB.199 version with a near-identical wing. The ultimate Kingston projects appear to have been the HS.1179L and M, again single and two-seat versions of the same aircraft. At low level with full fuel (10,900lb and 11,600lb [4,944kg and 5,262kg] respectively) and 4,000lb (1,814kg) of weapons their radius of action was 225nm (417km); they were limited to Mach 2.1.

On 30th July 1969 Hawker's Ralph Hooper, P.1127 Project Engineer from 1961 and Assistant Chief Designer (Projects) from 1963, told the MoD's Lt Cdr J O F Billingham that the 'L and M proposals, particularly the former, aim to be sensible engineering offers which do not evoke a brand new powerplant, which was perhaps the Achilles Heel of the 1154'. Lessons learnt from P.1154 were absorbed into the proposed layouts:

a. There was no fuselage bending structure beneath the engine which was, therefore, simply withdrawn beneath the fuselage.
b. The rear nozzles were close together and mounted in a hemispherical termination of the engine rear face. In this way the gas generator efflux was liberated beneath the fuselage close to the aircraft centreline which should avoid the buffet pick-up by the tailplane that the company had experienced on the Harrier.
c. HSA advised against demands for a higher top speed than was strictly necessary since the intake's variable geometry mechanisms began to escalate in weight and complexity above about Mach 1.8.

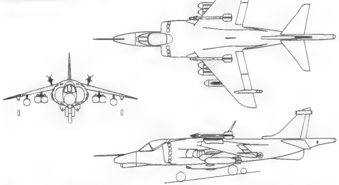
Hooper added that 'all of us on the engineering side at Kingston look forward to working on a second-generation V/STOL aircraft, by comparison with which a conventional aeroplane seems a very dull device'. He hoped that the worst excesses of 'multi-roleism' could be averted because that had contributed strongly to the death of the P.1154.

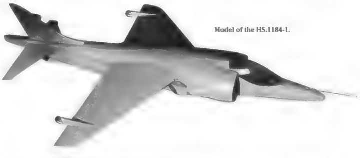
Brough's work, undertaken between July 1968 and February 1970, began with comprehensive parametric studies of fixed thrust line aircraft with boundary layer control (BLC) high-lift systems. These were backed up by small design studies aimed at producing the smallest, lightest aircraft to meet the requirements. A variable sweep aircraft received similar treatment and some characteristics of vectored thrust, such as structural design, were also examined using the HS.1179M as a basis since this layout was most likely to provide the best comparison with the aircraft the RAF expected to get out of the MRCA programme. Brough's conclusions suggested that a VG aircraft should not be a contender for the MRCA and that a BLC fixed sweep type produced the best aircraft except in landing performance. It was eventually established that a supersonic V/STOL proposal could not be considered against the MRCA requirements.

Hawker (Siddeley) HS.1184

HS.1184-0 was proposed in July 1970 and showed very little change to the standard Harrier outline except for a 24,500lb (108.9kN) Pegasus 15 with enlarged intakes, a cambered wing leading edge, uprated pylons and attachments and full nozzle reversal. Kingston felt a more suitable development would be the HS.1184-1 which had an extended nose for laser or radar, extended wing tips and the high fin of the T Mk.2 two-seat Harrier trainer. From wheels rolling and armed with four Taildog missiles, HS.1184-1 could reach 30,000ft (9,144m) in 3.05 minutes and 45,000ft (13,716m) in 6 minutes. It could carry two Sidewinder AAMs above the wing just outboard of the wing roots, six bombs on four underwing pylons and twin cannon packs beneath the middle fuselage; span was 29ft 7in (9.0m), length with probe 52ft 11in (16.1m).

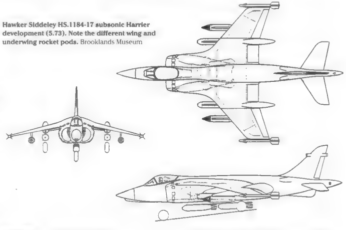
Hawker Siddeley HS.1184-1 subsonic Harrier development (7.70). Sidewinder AAMs are carried above the wing. Brooklands Museum



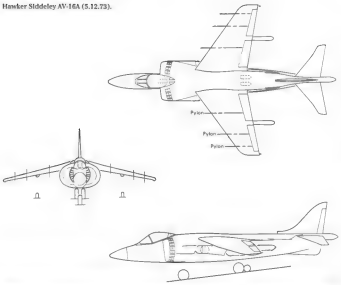


Model of the HS.1184-1.

Hawker Siddeley HS.1184-17 subsonic Harrier development (5.73). Note the different wing and underwing rocket pods. Brooklands Museum



Hawker Siddeley AV-16A (5.12.73).



Impressions of the AV-16 in the colours of (top to bottom) the USAF, RN, RAF and USMC. Rolls-Royce

Over the next four years many more designs were drawn under the HS.1184 banner. The HS.1184-17 for example had a Sea Harrier nose and a very different wing with the leading edges blended into the air intakes: span was 51ft 4in (15.6m), length 29ft 5in (9.0m) and wing area 288.5ft² (26.8m²). No interest in HS.1184 was forthcoming from the UK Government but it did lay the ground for the AV-16. The policy was that no more Harriers could be ordered because the Anglo-French Jaguar (see Chapter 13) was now under way and would fulfil all future requirements.

Hawker (Siddeley) HS.1185 and AV-16

Work on the HS.1185 began in 1970 and a short-lived Anglo-US study led to an aircraft called the AV-16 Advanced Harrier. A total of 110 AV-8A Harriers had been procured by the US Marine Corps (USMC) between 1971 and 1976 and a license agreement was established between HSA and McDonnell Aircraft (MCAir) which also covered joint studies for future developments. On 12th April 1973, following several months of close collaboration between Government agencies and UK and US industry, the go-ahead was given for an eight-month Programme Definition Phase for the jointly funded development of the AV-16 powered by a 24,500lb (108.9kN) Pegasus 15.

The preferred minimum change aeroplane was a subsonic attack aircraft and Phase 1 development was concluded in the closing weeks of 1973 and presented to the US and UK Governments. This was agreed and by spring 1974 further proposals had been completed. Essentially the aircraft would be similar to Harrier but with double the payload or combat radius. AV-16A had a broader fuselage to accommodate the larger diameter Pegasus 15 fan (for which reason the engine could not be retrofitted to existing aircraft), enlarged air intakes, a new wing of greater span and more area, raised cockpit, strengthened structure and undercarriage and new or revised avionics. A V-tail had been considered. Maximum VTO weight was 21,100lb (9,571kg), internal fuel totalled 6,500lb (2,948kg) and 300gal (1,364lit) drop tanks could be carried. The exhaust nozzles were to be strengthened and two alternative wing designs were available, developed by HSA and MCAir. The former was based on the so-called 'sonic rooftop' wing, the latter on super-critical work done by NASA; both were similar in sweepback and planform.

The RAF's aircraft would have seven stores points, a 30mm Aden and an undernose sensor. Both RN and USN aircraft (the latter for the new Sea Control Ship) would have nose-mounted radar with the American machines carrying Sidewinder or Sparrow AAMs and Harpoon, Maverick or Condor ASMs. The first of two YAV-16A prototypes was expected to fly in America at the start of 1977; the first AV-16A would also fly in America in mid-1979. The USMC was expected to take 342 aircraft but the development costs (especially for the new engine) were unacceptable, particularly against a background of worldwide increases in inflation, and Britain pulled out in March 1975. This precipitated the AV-16's demise and the two countries went their separate ways, Kingston replacing it with new wing investigations for Harrier (see below).

Some supersonic versions were also drawn. One, the HS.1185-6 (AV-16S-6), showed the first steps taken to move the jet streams away from the rear fuselage and empennage – jet streams which brushed the flanks of the rear fuselage and passed closely under the wing and tailplane were one of the less desirable features of the Harrier configuration. The later P.1205 series of fighters took the separation of engine nozzles and the rear portions of the airframe as far as possible within the constraints imposed by a conventional layout.

Model of the Hawker Siddeley Big Wing Harrier GR Mk.5 (13.7.78). BAE Systems

Big Wing Harrier

In the mid-1970s HSA Kingston realised that before the end of the decade a new version of Harrier would be needed to supplement and later supplant the original RAF 'Jump-Jets' and the Big Wing concept began with informal talks between the MoD and HSA. The basic theme was that present Harriers were effective in their main role of ground attack and reconnaissance but lacked self-defence capability; a new wing with increased lift and carrying AAMs would improve this without reducing the offensive load. More internal fuel was also wanted so, in short, what was required was a bigger, better wing with six pylons that could be retrofitted to existing aircraft. An MoD-funded programme had also investigated the fitting of leading-edge root extensions (LERX) to the Harrier and wind tunnel data and flight trials indicated that this gave useful increases in usable lift at high angles of attack.

Prior to this, the near total lack of interest shown by the UK Government through the late 1960s and early 1970s towards developing the Harrier had led to the initiative crossing the Atlantic. In 1974/75 McDonnell Douglas proposed to the US Government a modified AV-8A which would provide increased capability, including twice the original's bombload radius, while importantly using the same basic engine. The result was the AV-8B Harrier II. Changes were principally a new, greater area carbon fibre composite wing which incorporated large slotted flaps for improved STO performance, six pylons, underfuselage strakes and a cross-dam for better VTO performance, and an improved efficiency engine intake. This was a joint McDonnell/HSA design for which Kingston had a big team of designers based at St Louis.

The first of two prototype YAV-8Bs, converted from AV-8As, flew on 9th November 1978. The American wing had many of the features desired for the UK's aircraft but it was unsuited for retrofit. A UK evaluation team tested a prototype in 1980 and found that, whilst it performed well in its design role as a close air support 'bomb truck', it had two notable deficiencies. First, top speed at low altitude was more than 57mph (92km/h) slower than existing RAF Harriers and, second, whilst manoeuvring performance was better than Harrier, rate of turn was still less than required (production AV-8Bs were expected to be better).

In October 1977 Kingston received a contract for a feasibility study to replace the existing wings on GR Mk.3 or T Mk.4 aircraft with what was now officially called the Big Wing. This had a greater span and area, carried three pylons per side and its aerodynamic design used the latest supercritical technology. LERX were fitted which contributed to a much better air-to-air combat capability and Harrier's plain flap was replaced with a single-slotted flap of increased span to improve STO and combat manoeuvring performance. The Big Wing was constructed in metal, not carbon fibre (carbon was later to be used for new-build aircraft to save 300lb [136kg] in weight). Internal fuel rose to 880gal (4,001lit) from the GR Mk.3's 632gal (2,874lit) and the fuselage was based on the Royal Navy's Sea Harrier fighter with a raised cockpit and more space for sensors and equipment.

When hovering at less than 10ft (3.0m) above the ground the Harrier experienced a

The first full-scale McDonnell Douglas AV-8B prototype seen during its first brief hover at St Louis on 5th November 1981. It completed its first conventional landing and take-off the following day.

Artist's impression of a 'Future Concept' Harrier III from the late 1980s. BAe

strong up-flow due to the mutual interference of the four jets spreading over and being reflected by the ground. The pressure recovery of this up-flow beneath the aircraft's belly was enhanced on Big Wing Harrier by large strakes and a retractable 'cross-dam' mounted respectively on and between the gun pods; these features were called Underfuselage Cushion Augmentation Devices. This idea had been patented in the early days of the P.1127 and further developed by McDonnell Douglas for the AV-8B. The aircraft could lift off vertically with nearly 1,500lb (680kg) more fuel or external stores than the GR Mk.3, or with an extra 3,000lb (1,361kg) from a 1,000ft (305m) ground run. Other performance figures, particularly low-level turn rate, were also much improved.

The resulting configuration came to be referred to as the GR Mk.5 and it was expected that a five-year development programme could be met with service entry in 1985. Kingston stressed that the choice was the Big Wing Harrier or the AV-8B which was a 1974/75 concept and which would not enter service itself until 1985, after ten years of development. BAe feared that if the MoD ordered the AV-8B it would be re-importing original British technology in an inferior product, when BAe itself was a world leader in the V/STOL field However, an MoU was signed in August 1981 to buy AV-8Bs significantly modified to ASR.409, with two extra Sidewinder AAM dedicated pylons, as the Harrier GR Mk.5. The MoD's choice was based on cost. Ninety-six were eventually ordered, the first development aircraft flew on 30th April 1985 and the type entered RAF service in 1988; they were later upgraded to GR Mk.7 standard. All AV-8Bs and GR Mk.5s were built jointly by McDonnell Douglas and BAe on a 50/50 work-split basis.

Alongside the Big Wing and Advanced Harrier studies, Kingston continued research into more advanced V/STOL ideas. The HS.1205, P.1212, P.1214 and P.1216 series is described in *British Secret Projects: Fighters* but there were others including the following.

BAe Kingston P.1208

This was a 1978 project for a survivable ground attack type with air combat capability. A meeting held at Kingston on 30th May agreed that the aircraft was to be based on 'the essentials of the Harrier but it would be a totally new STOVL airframe'. P.1208 was considered as a replacement for Harrier and a 'fallback' option to the very much more expensive, supersonic vectored thrust P.1205 (ex-HS.1205) fighter to AST.403. How P.1208 would compare with the various big wing developments of Harrier would have to be carefully defined otherwise its advantages would not be clear. The engine was based on the existing Pegasus and there would be four nozzles, although a three-nozzle arrangement would be considered after tests. PCB would not be fitted and the engine rating would emphasise combat thrust, say 23,000lb (102.2kN), rather than take-off thrust.

The aircraft had to be able to sustain high g at low speed and low altitude and STOVL was required with a soft field capability superior to Harrier. P.1208's carbon fibre composite construction was identical to the P.1205's with its wing loading slightly above the level of the conventional P.1202 (ex-HS.1202) fighter. Leading-edge and trailing-edge flaps, and leading-edge strakes, were fitted and two Sidewinder AAMs were to be carried as standard with two inboard-mounted guns and six wing pylons for other stores. The aircraft was seen as a single-seat design and clamours for two seats were to be resisted. P.1208-1 had side intakes and a conventional swept wing. P.1208-2, dated 15th September 1978, introduced a chin intake, a canard and forward sweep wings.

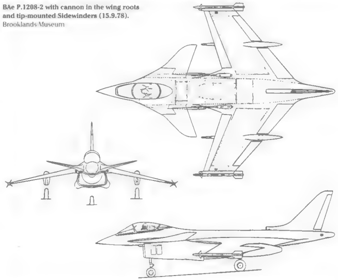
BAe Kingston P.1209

By 1979 the original P.1127 subsonic demonstrator had led to a still-growing family of operational aircraft projects right up to the ASR.409 'Advanced Harrier'. Without the P.1127, and the establishment of operational concepts using the Kestrel, it was unlikely that the Harrier would have appeared. With the P.1154, Kingston had recognised the possibility for supersonic V/STOL and since then had studied virtually every possible supersonic STOVL configuration but repeatedly found that the single-engined vectored thrust with PCB concept gave the best cost-effectiveness compatible with acceptable pilot safety. However, a lack of flight evidence was a weakness and, with a long-term programme for further subsonic V/STOL aircraft in place (ASR 409), Kingston felt a market for a supersonic type was unlikely before 1990. The company realised that a UK-only supersonic V/STOL demonstrator would be an important step and defined the idea in its P.1209 brochure of 30th March 1979.

This would look at the interaction between the jets and airframe, the optimum nozzle shape and their location on the fuselage, and the balancing of the centres of thrust, lift and mass. Calculation and tunnel tests could in part resolve these issues but, as at the time of the P.1127, this was inadequate for ensuring a design that was satisfactory in all respects. Although the initial P.1127 design was substantially correct, improvements in performance, control and safety resulted from its early flight trials. Differences between a supersonic V/STOL aircraft with PCB and the Harrier included the need for larger front nozzles with an efflux of higher temperature and velocity and a proportionately greater fuel load due to the PCB's higher fuel consumption. Larger nozzles had already been model tested.

Although a supersonic V/STOL aircraft would in some respects operate quite similarly to Harrier, in others it would differ. Its missions, equipment and operational systems would not be the same and PCB, with its higher temperature and fuel consumption, would need special handling techniques. The choice of what demonstrator to build centred on an elaborate ground rig or 'bedstead', fitting PCB into a standard Harrier, designing a

BAe P.1208-2 with cannon in the wing roots and tip-mounted Sidewinders (15.9.78). Brooklands Museum



simple metal airframe around a PCB engine using as many existing parts as possible, designing a new metal airframe with Mach 1.6 potential (P.1209), or producing the P.1205 with all its other technical innovations. The brochure suggested that the 'bedstead' and converted Harrier could test V/STOL but not the correct airframe representation, so their results would be a useful guide but not proof of feasibility. The simple airframe could not test the supersonic potential but would cost nearly as much as P.1209 since the major expense was the development of PCB, while P.1205 would commit everyone to much greater spending before proof of feasibility. On balance, P.1209 represented a minimum cost airframe capable of demonstrating PCB in V/STOL and supersonic operations.

The chosen configuration, the P.1209-2, had a Pegasus 11F-33C (the AV-8B's 11-35 fitted with PCB) and was shaped so that the aerodynamic flows were very similar to those expected for the operational P.1205. Conventional metal skin and stringer construction was used and active control technology (ACT) was not included. The extra weight from not using carbon fibre was more than compensated for by the absence of operational equipment, such as radar and guns, and the reduced flight envelope conditions selected. Wing, fuselage and tail would be very similar to the P.1205-11 but rear nozzle area was increased by 7% and the front nozzles were slightly smaller; nominal PCB temperature was 1,600°K and fuel capacity was expected to be 9,000lb (4,082kg). Every opportunity would be taken to use existing hardware and provision would be made for the trial carriage of dummy wing tip Sidewinder AAMs and dummy tanks or stores on undercarriage and inboard wing pylons. With PCB off, maximum level speed in clean condition would be about Mach 0.96; with PCB on, Mach 1.54. With wing tip AAMs these dropped to 0.95 and 1.48 respectively (with tip AAMs, P.1205-11 could reach Mach 1.54).

BAe Kingston P.1226

This project looked at proposals for a third-generation V/STOL aircraft. P.1226-1 was essentially a subsonic version of the P.1216 twin-boom fighter; P.1226-2 had a Harrier-type fuselage but with a canard and forward-swept wings. The fuselage had been stretched by inserting an 18in (45.7cm) plug behind the pilot and another 36in (91.4cm) plug to the rear of the Pegasus. Two of the latest Sidewinder AAMs were carried on the wing tips, two gun packs were mounted under the fuselage, the inner undercarriage pylons could each carry two bombs or other stores and there were two more underwing pylons per wing. Span was 30ft (9.1m), length 50ft 10in (15.5m), wing area 269.7ft² (25.1m²).

The key to Harrier's success, apart from its simple basic configuration, has been the vectored thrust Bristol Pegasus turbofan which was specifically designed for V/STOL applications as the BE.53 and first run in August 1959. Thrust vectoring is achieved by four rotatable nozzles simultaneously operated and symmetrically positioned on each side of the engine, outside the aircraft's fuselage. The front nozzles discharge bypass air whilst the rear nozzles discharge the turbine efflux. To minimise control problems in the aircraft, the resultant total thrust from the four nozzles passes through a fixed point, the thrust centre, regardless of nozzle angle. High-pressure compressor bleed air is used to control and stabilise the aircraft in jetborne flight. The Pegasus has been progressively improved and uprated allowing developments from the P.1127 through to the Harrier II and beyond; the engine always led and Kingston designed to the thrust available from the engine as it was developed. However, anything powered by a dry Pegasus will be subsonic because, like all turbofans, it has a low jet velocity; supersonics need PCB or reheat.

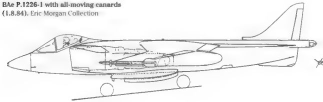
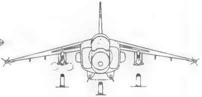
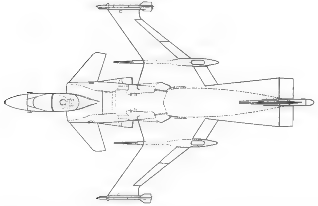
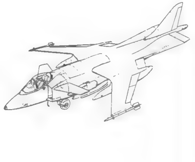
Bristol Siddeley's BS.100 for the P.1154 was a larger turbofan engine in which, to boost thrust for take-off, climb and supersonic flight, the fan flow to the front nozzles passed through a duct (or plenum chamber) incorporating fuel injectors and combustion stabilisers. This method was termed Plenum Chamber Burning and was efficient because, unlike afterburning in the already very hot turbine exhaust, burning was taking place in a relatively cold gas stream. Compared with a dry Pegasus, thrust boost in the powered lift mode was 35% to 40% and at high altitude 100%.

Bristol's vectored thrust engines proved to be a thorn in the flesh of Rolls-Royce who favoured separate vertically mounted lift jets. On 30th May 1962 Rolls' Adrian Lombard wrote that it was 'significant that all future combat aircraft will call for V/STOL characteristics which we pioneered through the Meteor deflected thrust, Ryan Vertijet, Flying Bedstead and Short S.C.1 research aircraft, and we have done more than any other establishment to publicise the technical and tactical advantages of VTOL by direct jet reaction. Perhaps the most important military business is associated with future NATO projects such as the NBMR.3 strike reconnaissance project and a major issue will be which of the two alternative VTOL powerplant systems will be selected. A factor of major concern is the British Government's support of the Hawker P.1154 with its BS lift/thrust engine (presumably because of their earlier support of the STOL Hawker P.1127) without regard to the fact that the majority of aircraft designers have confirmed our powerplant solution.' Most NBMR.3 projects had lift jets, but the fact that the only non-Soviet V/STOL aircraft to enter service used a single lift/thrust engine tells its own story.

The Harrier eventually beat all of its competitors, but it needed luck. The late Dr John Fozard, Chief Designer, Harrier, from 1965 to 1978, wrote that 'the energy release of the P.1154 in V/STOL would have constrained the choice of surfaces and sites very much more than has proved acceptable with the "softer" non-PCB Pegasus in the subsonic Harrier which replaced this cancelled project. It is possible that such a difficult and limiting experience with the first Service use of jet V/STOL might well have led to the supporting air arm, as well as all others, to turn away from off-base jet STOVL, convinced of its impracticability. Thus, by a turn of politics and of history, we are fortunate that the modest-energy, modest-footprint, subsonic Harrier became the first in service, so providing the RAF with demonstrable practicality and hence ensuring a positive future destiny for jet V/STOL in the field.' Dr Fozard was sure that the P.1154 could have been satisfactorily developed but he felt that, viewed with hindsight, in 1965 it was 'an aircraft whose time had not yet come.' Its cancellation was a big disappointment but it would not have sold as well as the P.1127.

To date, no supersonic V/STOL aircraft has entered service anywhere in the world. Currently the UK has a significant design share in the American Joint Strike Fighter (JSF), particularly as an option to equip its planned future aircraft carriers. This aircraft could become the first supersonic V/STOL to reach a squadron, but that stage is a long way off and a lot of money, and politics, needs to be expended before we know if it will get there.

BAe P.1226-1 with all-moving canards (1.8.84). Eric Morgan Collection

NBMR.3 Projects – Estimated Data

Project	Span ft in (m)	Length ft in (m)	Wing Area ft² (m²)	t/c %	All-Up-Weight lb (kg)	Powerplant Thrust lb (kN)	Max Speed Height mph (km/h) ft (m)	Weapon Load lb (kg)
BAC (Vickers) Type 584	41 2 (12.6) forward, 25 5 (7.7) swept	56 3 (17.1)	397 (36.9) forward, 382 (35.5) swept	c10 forward, c5 swept	36,000 (16,330), 44,000 (19,958) (naval version)	1 x RB.177-1R Medway 27,300 (121.3) reheat, plus 8 x RB 162-6 4,400 (19.6)	NBMR 3 Mach 1.1 at sea level, Mach 2.16 above 40,000 (12,192); Navy Mach 2.49 at 55,000 (16,764)	Minimum 3,000 (1,361) of stores
Short P.D.56	28 0 (8.5)	54 6 (16.6)	?	?	29,700 (13,472) (VTO max.)	1 x RB 168-1R reheated Spey, 8 x RB 162-2 4,400 (19.6)	Mach 1.08 at sea level, Mach 1.95 at 40,000 (12,192) (with 1,000lb load)	Maximum 2,400 (1,087) of stores including Bullpup, 1,000 (454) bombs and nuclear
Hawker P.1154	26 0 (7.9)	55 4 (16.9)	244 (22.7)	not given	28,795 (13,061) normal	1 x BS 100/9 33,150 (147.3) reheat	Mach 2.4 at 36,000 (10,973)	1 x nuclear or 2 x 1,000 (454) bombs under fuselage, ASMs, AAMs, bombs or RPs under wings
Hawker P.1155	26 0 (7.9)	54 8 (16.7)	244 (22,7)	not given	c28,800 (13,064)	1 x BS.53/5, 2 x RB.162	Mach 2.3 at 36,000 (10,973)	1 x nuclear or 2 x 1,000 (454) bombs under fuselage, ASMs, AAMs, bombs or RPs under wings

Kingston Vertical Take-Off Projects – Estimated Data

Project	Span ft in (m)	Length ft in (m)	Wing Area ft (m)	t/c %	All-Up-Weight lb (kg)	Powerplant Thrust lb (kN)	Max Speed Height mph (km/h) ft (m)	Weapon Load lb (kg)
P.1127 (19.8.57)	20 0 (6.1)	34 0 (10.4)	154 (14.3)	9	11,000 (4,990)	1 x BE 53 11,350 (50.4)	706 (1,136) at sea level, 639 (1,028) at 30,000 (9,144)	1,000 (454) bombs, RP dispensers, napalm tanks
P.1127 (flown)	24 4 (7.4)	49 0 (14.9) with probe	185 (17.2)	?	Initially approx. 11,800 (5,352)	1 x BE 53/3 Pegasus 2 initially 11,300 (50.2)	720 (1,158) at sea level, Mach 0.97 at 36,000 (10,973)	None
Harrier GR Mk.1 (flown)	25 3 (7.7)	45 6 (13.9)	201 (18.7)	10.1 centreline 3.9 tip	25,000 (11,340)+	1 x Mk 101 Pegasus 6 19,000 (84.4)	740 (1,191) at sea level, Mach 1.3 in dive at altitude	2 x detachable 30mm Aden gun pods, maximum 5,000 (2,268) of stores
HS.1175	29 0 (8.8)	56 6 (17.2)	237 (22.0)	not given	31,550 (14,311)	1 x Pegasus 103 21,000 (93.3), 1 x XJ-99 8,200 (36.4)	Mach 0.90 685 (1,102) at sea level, Mach 0.94 622 (1,001) at 36,000 (10,973)	Maximum 10,000 (4,536) of stores
HS.1179L (1969)	30 6 (9.3)	51 6 (15.7)	300 (27.9)	not given	39,200 (17,781)	1 x Pegasus 9D-03 34,000 (151.1)	Mach 1.15 875 (1,408) at sea level, Mach 2.1 1,382 (2,223) at 36,000 (10,973)	Maximum 10,000 (4,536) of stores
HS.1179M (1969)	30 6 (9.3)	55 9 (17.0)	300 (27.9)	not given	43,800 (19,868)	1 x Pegasus 9D-03 34,000 (151.1)	Mach 1.13 860 (1,384) at sea level, Mach 1.9 1,255 (2,020) at 36,000 (10,973)	Maximum 10,000 (4,536) of stores
AV-16	30 4 (9.24)	46 6 (14.2)	230 (21.4)	11.5 root 7.5 tip	28,000 (12,701)	1 x Pegasus 15 (Mk 201 F402-RF-403) 24,500 (108.9)	720 (1,158) combat speed	See text
Big Wing Harrier	32 0 (9.8)	46 10 (14.3)	250 (23.25)	9.2 tip 12.5 centreline	25,592 (11,609) (4 x BL755, 2 x AIM-9L)	1 x Pegasus 11-35 22,700 (100.9)	c740 (1,191) at sea level	2 x AAMs, 2 x cannon, 1,000 (454) bombs, BL755 cluster bombs, or RP launchers on 8 underwing pylons
P.1208-2	29 0 (8.8)	44 5 (13.6)	290 (27.0)	not given	?	1 x Pegasus 11-35	Mach 0.95	2 x AAMs, 2 x cannon, 6 x bombs
P.1209	30 10 (9.4)	52 9 (16.1)	300 (27.9)	not given	27,443 (12,448)	1 Pegasus 11F-33C 22,840 (101.5) PCB off, 32,220 (143.2) PCB on	Mach 1.15 at sea level, Mach 1.54 at 36,000 (10,973)	Dummy AAMs and bombs

Over the Sea

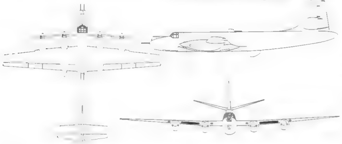
An evocative Avro view of the first Shackleton MR Mk.3, WR970, banking away from the camera in the mid-1950s.

Anti-Submarine Aircraft: 1945 to 1969

The term 'bomber' embraces all manner of aircraft types designed to deliver bombs, missiles or other weapons at targets on or in the ground or sea. The aeroplane may have been produced specifically to convey bombs to a target or, instead, bombing may be just one of a number of roles allocated to it. One of the more unsung types is the anti-submarine (A/S) aircraft based either on land or in aircraft carriers. This type's ability to undertake long-endurance patrol flights over water will probably mean that it will be quite different to the high-performance types described in most of the rest of this book. It will need to be relatively slow and economic to fly so, as a result, it may well be piston or turboprop powered. Over the years the anti-submarine aircraft has been called upon to perform a vital role.

During World War Two Allied anti-submarine aeroplanes operating from coast or land bases encompassed flying boats like the Short Sunderland or adapted long-range bombers such as the American Consolidated B-24 Liberator. The Short Shetland flying boat, a successor to the Sunderland which flew in

December 1944, was intended to continue this trend but it never entered service. Even as late as November 1948 a specification was issued for a maritime reconnaissance flying boat to replace the Sunderland; R.2/48 called for a bomb load of up to 8,000lb (3,629kg) and projects tendered to it included the Saro P.162 Duchess, Blackburn B.78, Short P.D.2 and Supermarine Type 524. In early 1950 Shorts were informed that they were likely to win the contract for R.2/48 (which was to be renumbered R.112D) but by 1952 it was clear that a flying boat was no longer required to patrol the Atlantic and the aircraft was never built. The Avro Shackleton, operating from conventional runways, was seen as the way forward.



Avro 716 (19.10.50). Avro Heritage Centre

Avro Shackleton

Derived from the Avro Lincoln heavy bomber, the Avro Type 696 Shackleton MR Mk.1 was essentially a wartime design produced to specification R.5/46 and OR.200, the first prototype flying on 9th March 1949. There appears to have been no competition to the Type 696 from other British aircraft companies. The type entered service in April 1951 and 77 Mk.1s or Mk.1As were built followed by another 69 Mk.2s. In due course OR.320 appeared for an improved long-range maritime reconnaissance aircraft to fill the gap left by the withdrawal of the last Sunderlands. The leading competitor was a Shackleton Mk.3 but the Saro P.162 and Canadair CL.28 (a Canadian development of the Bristol 175 Britannia airliner which became the Argus) were, for a period, also in the picture.

Avro 716 Shackleton Mk.3

By October 1950 Avro felt that the Shackleton Mk.2 with its existing Rolls-Royce Griffon engines represented the limit of development for the aircraft in its present form. The Type 716, a direct development of the Mk.2, offered an increased radius of action and a higher cruise speed which would cut the duration of the outward and return flights, whilst its slow flying qualities would allow a maximum search time over the target area. Avro wanted an engine with the lowest possible specific fuel consumption, even at the expense of extra weight, so the Griffons were replaced by Napier Nomads which, compared to current supercharged piston engines, offered more flexibility of operation between sea level and 20,000ft (6,096m). In addition the Nomad exhaust system would be extremely quiet, noise having been a major problem with the Mks.1 and 2.

A new wing would carry the necessary extra fuel (total capacity 4,400gal [20,006lit]) and improve the aircraft's aerodynamic efficiency. High-lift double-slotted flaps would give a marked improvement in take-off and landing characteristics while it was proposed to fit multi-wheel main units and dual nosewheels so that runway loadings might be considerably reduced when compared with the Shackleton Mk.2, despite a much higher take-off weight. Experience from the Mk.1 relating to the influence of the slipstream on longitudinal stability and trim meant that the 716's tailplane was now attached to the base of a single fin and rudder. This was raised by dihedral to a sufficiently high position to alleviate the reduction in longitudinal stability usually associated with the 'power-on' condition. In addition the size of the tail was increased to accommodate the large changes in trim experienced when lowering and raising the high-lift flaps.

The second Avro Shackleton prototype, VW131 with the original nose and gun mountings on the sides.

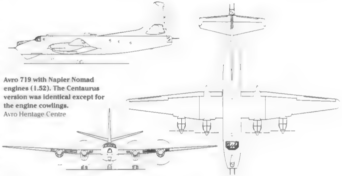
WL752 was an Avro Shackleton MR Mk.2 and is seen at Nicosia in late summer 1955. Note the revised nose. Colin Cole Collection

Type 716 used all-metal construction and reintroduced the twin 20mm nose cannon while the Nomads were fitted with co-axial propellers. Sea level rate of climb was estimated to be 970ft/min (296m/min), compared to the Mk.1's 730ft/min (223m/min), service ceiling 24,600ft (7,498m) and still air range at 5,000ft (1,524m) 3,580nm (6,630km) (Mk.1 18,600ft [5,669m] and 2,620nm [4,852km] respectively). An Appendix gave brief details of an alternative and completely new proposal which had a wider circular fuselage, a more compact bomb compartment to accommodate two 'Pentane' weapons side by side and a new stressed-skin wing. By December, Avro favoured this later project more than the original proposal.

Avro 719

The Avro 717 Shackleton test bed was intended to fly with two Napier Nomad engines in the outer nacelles. The Type 719 was another Mk.3 proposal from January 1952 with a new fuselage and four Nomads on standard outer wings. Coastal Command's draft requirements were now looking at eight hours search at an operating radius of 1,000nm (1,852km) together with good manoeuvrability and minimum noise and vibration. Thanks to the need for economy in the design and manufacturing effort, the Type 719 offered an alternative to the 'final' 716 based on the present Mk.1 and 2 wing. The outer wing was unchanged but a new centre section of increased span was introduced offering greater fuel capacity and aerodynamic efficiency. Existing jigs could be used for construction and the new aircraft could follow the Mk.2 Shackleton production line.

It was proposed to modify the wing structure aft of the rear spar to incorporate ailerons of increased power at the outboard end and high-lift flaps over the inboard and centre sections. The former would give increased rolling power and the latter short take-off and landing distances in spite of a higher all-up-weight. The chosen powerplant was the Napier Nomad compound engine but, pending its development to a standard suitable for service use, it was proposed initially to fit four Bristol Centaurus 660 radials. The installation was designed so that it was possible to convert from Centaurus to Nomad with the minimum of work. To keep down runway loading the main undercarriage would use four-wheel, eight-tyre bogie units that were substantially the same as those on the Avro 698 (Vulcan). The fuel capacity was 4,710gal (21,416lit) and a rear turret was introduced. Avro believed that if an order was placed in May or June of 1952, the first aircraft could be flying in August 1954.



Avro 719 with Napier Nomad engines (1.52). The Centaurus version was identical except for the engine cowlings. Avro Heritage Centre

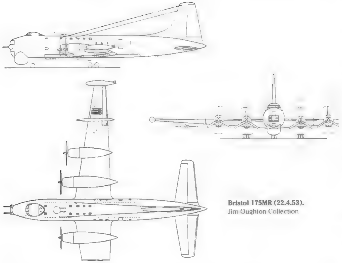
Bristol 175

In October 1951 Bristol submitted a proposal for a maritime reconnaissance variant of its Type 175 Britannia airliner which the company then revised in January 1952 with four 3,150shp (2,349kW) Napier Nomad N.Nm.6 engines. The later variant's estimated weight was 147,000lb (66,679kg) and it would carry up to 8,000lb (3,629kg) of offensive stores, patrol at 173mph (278km/h) between sea level and 5,000ft (1,524m) and give an endurance for the 1,000nm (1,852km) radius of action of 12 hours.

By now a draft requirement was in place for a Shackleton replacement but, because the companies knew little about it, the Avro 719 and Bristol 175 development were both prepared based on a guess of what might be required. They were assessed together from February 1952 and both had front, mid-upper and tail turrets each with two cannon, the specification suggesting two Adens in the front and rear turrets, 20mm in the dorsal position. Some within the Ministry felt the 175 offered the best solution because the Avro 719 would not give a reasonable combination of range and endurance. Despite being a new design, the 719 was thought to be too small to give an acceptable patrol time and it had no development future.

At 135,000lb (61,236kg) all-up-weight the 175 offered around twice the patrol time of the 719; as a variant of a civil aircraft its development and production costs should be lower and it would benefit from subsequent increases in power from the Nomad. However, neither project could operate from a 2,000-yard (1,829m) runway at high enough weights to give a suitable endurance, partly because the take-off power of the Nomad during the early stages of development would be 3,050shp (2,274kW). Some thought was therefore given to fitting rockets for take-off assistance but this would rob both proposals of their main attraction, i.e. the use of wings or part wings already developed for other aircraft. In tropical conditions the 175 would need a considerable weight of rockets to get off in under 2,000 yards and the Ministry doubted if the Nomad would give its full power in time (the expected fully developed figure of 3,500shp [2,610kW] would be sufficient to meet the runway limits). In contrast, Coastal Command felt the 719 had many good features but they wanted any new very long-range MR aircraft to be a flying boat rather than a landplane.

In September 1952 Avro submitted its Shackleton Mk.IIA brochure, a more conservative design compared to the 719 with four Griffon 57s. Despite lacking the crew comfort of both of the above projects it offered a slightly longer patrol time (the Shackleton III/719 gave higher drag) and, after being confirmed as acceptable to the RAF in January 1953, it was eventually ordered as the MR Mk.3. The aircraft retained the twin fins but it introduced a tricycle undercarriage, increased wing fuel, a different cockpit canopy and better interior sound-proofing. A total of 34 were built for the RAF, the first flying on 2nd September 1955.

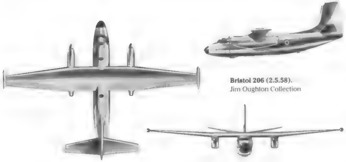


Bristol 175MR (22.4.53). Jim Oughton Collection

Bristol 175MR

In 1953 Bristol took its development of the Britannia airliner a stage further with this project whose forward fuselage was reminiscent of the wartime Short Stirling bomber. The Britannia's Bristol Proteus turboprops were replaced by American Wright R3350-32W radials with 15ft 6in (4.72m) diameter Curtiss Electric three-blade propellers and the project had a Bristol Type N nose turret with two 20mm cannon and, provisionally, a Bristol B.17 dorsal turret with two more. A large lower fuselage bomb bay could hold a mix of anti-submarine weapons while rocket projectiles and other missiles could be fired from positions beneath the outer wing. Span with tip tanks was 144ft (43.9m), length with nose guns 123ft (37.5m) and wing area 2,060ft² (191.6m²). The Bristol Type 189 was a similar project powered by Napier Nomads.

By 1958 thoughts had moved on towards a medium-range replacement for the Avro Shackleton. In addition NATO had opened a competition between European aircraft manufacturers for a maritime patrol aircraft to replace the American Lockheed Neptune in European air forces (during the 1950s the Neptune served with Coastal Command as a stopgap). The required aircraft would carry about 6,000lb (2,722kg) of search equipment and offensive armament on a basic mission consisting of either a four hour search period at 1,000nm (1,852km) radius from base or an eight hour search period at 600nm (1,111km) radius. The search was to be undertaken at sea level and a transit speed of 300 knots (345mph/559km/h) was required. A number of competing designs were submitted before the Breguet 1150 Atlantic was chosen as the winner; at least three came from British manufacturers.

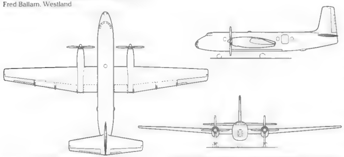


Bristol 206 (2.5.58). Jim Oughton Collection

Bristol 206

This carried 4,410gal (20,052lit) of fuel and was powered by two Rolls-Royce Tyne turboprops with 16ft (4.88m) diameter propellers. Besides the standard A/S stores in the weapon bay, the Type 206 could also carry one Bullpup ASM on a pylon under each wing placed midway between the engine nacelle and tip pod. A retractable ECM radome was housed in the lower fuselage level with the propellers, the port wing tip pod contained a searchlight and the starboard wing tip pod housed missile electronics.

Fairey NATO Maritime Patrol Aircraft (21.6.58). Fred Ballam, Westland



Photograph on the opposite page.

Impression of Fairey's NATO Maritime Patrol Aircraft. Fred Ballam, Westland

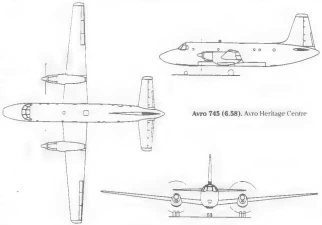
Fairey NATO Maritime Patrol Aircraft

Since primary cost as well as economy of operation were of fundamental importance to this requirement, Fairey had made a number of preliminary studies to determine the minimum size of aircraft that would comply with the required operational characteristics. Like the other competitors described here, the company concluded that a twin-engined land-based aircraft represented the most suitable solution. At the required speeds the propeller-turbine was superior in efficiency to the pure jet while ease of maintenance ruled out mixed powerplants, the very sophisticated compound engine or coupled versions of existing single engines. Fortunately an existing turboprop, the Tyne, was available and two Mk.11 units were fitted with 16ft (4.88m) propellers.

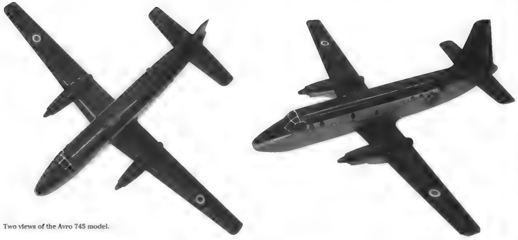
Semi-monocoque predominantly aluminium skin construction was used throughout and a multi-spar wing was fitted. Maximum continuous cruising speed at the 81,000lb (36,742kg) take-off weight was 355mph (571km/h) at 30,000ft (9,144m) and 350mph (563km/h) at sea level. Rate of climb was 2,190ft/min (668m/min) and service ceiling 34,500ft (10,516m); at 75,000lb (34,020kg) the service ceiling became 36,600ft (10,973m) – the specification requested 20,000ft (6,096m). Total fuel load was 31,200lb (14,152kg).

Avro 745

Avro felt that the high transit speed could be best met by cruising at medium altitude and using gas turbines, again Tyne turboprops driving 16ft four-bladed de Havilland propellers. A twin-Tyne aircraft would meet all of the Specification requirements but a four-engined aircraft could be powered by Rolls-Royce Dart 10s or the proposed Bristol Siddeley Mamba 10. The Dart aircraft would be appreciably heavier while the twin-Tyne and four-Mamba versions would have similar weights. The Tyne, already under development for the Vickers Vanguard airliner, was preferred.



Avro 745 (6.58). Avro Heritage Centre



Two views of the Avro 745 model.

To obtain an efficient wing structure the complete torsion box had to pass through the fuselage and, since the 745's wing was located below the fuselage floor, this resulted in a split bomb bay with one part forward and the other aft of the wing centre section. Any required store could be carried in either bay while the low wing offered the best characteristics in the event of ditching. The wing structure was of the fail-safe type, the main torsion box consisting of front and rear webs with skins stiffened by Z-section stringers. Most of the wing torsion box formed an integral fuel tank while high-lift Fowler-type flaps and conventional sealed balance ailerons occupied the wing trailing edge. Fuselage structure was conventional consisting of formers and stringers attached to the skin.

An ASV.21 search scanner was located in the forward end of the fuselage ahead of the bomb bay and could retract within the fuselage contours to give minimum drag when cruising; the whole scanner could be jettisoned to open the forward parachute exit. A complete cabin mock-up of the 745 was constructed at Avro's Manchester headquarters. Fuel capacity was 3,860gal (17,551lit), estimated sea level rate of climb 2,280ft/min (695m/min), service ceiling 32,200ft (9,815m) and patrol speed 196mph (315km/h). The eight-hour/600nm radius requirement was achieved but the 745's patrol time at 1,000nm was higher at 5.4 hours. The three finalists in the competition were the Avro 745, a design from Nord and the Breguet 1150; the latter was chosen on 21st October 1958.

Hawker Siddeley HS.801 Nimrod

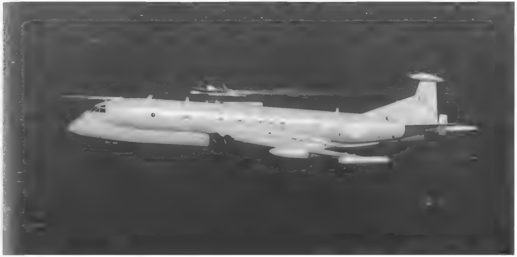
During the early 1960s the search for a Shackleton replacement continued under OR.350 and specification MR.218, to which competing Hawker Siddeley designs were a version of the Comet airliner with four RB.168 jet engines, the Avro 776 project with three Medway jets, a version of the Trident airliner, a Shackleton development (which did not meet the specification) and the Breguet Atlantic; BAC's offers were versions of the Vanguard and VC-10 airliners. This was succeeded by AST.357 which again received numerous proposals including the P.D.69 from Shorts and further versions of current British airliners. The Shackleton Mk.2 was to be replaced by the AST.357 aircraft in about 1970 but a reappraisal in 1964 indicated that the latter would not be available until about 1978 and noted that it would be unwise to keep the Shackleton 2s in service until then.

As a result ASR.381 and MR.254 for an interim maritime reconnaissance aircraft were written around the Breguet Atlantic specification since that aircraft was the contender with the minimum acceptable performance. The requirement was issued on 19th June 1964 and further contenders were examined by the MoA and industry. Final proposals were due on 14th December and the winner was the HS.801 Nimrod, an extensive redesign of the Comet airliner which beat a variant of the Trident called the HS.800. A careful assessment was also made of the Atlantic and the American Lockheed P-3 Orion but, in terms of the radii of action and weapons loads needed for Britain's worldwide task, neither was considered by the Air Staff to be cost-effective compared to the HS.801.

The aircraft's configuration was agreed on 30th September 1965 and two Comets were flown to Woodford for conversion to HS.801s; the first flew on 23rd May 1967, the same month that the new type was named Nimrod. On 19th January 1966 a contract was signed for 38 production aircraft and the type entered RAF service in 1969; it serves to this day although, despite upgrading, its systems are now getting a bit long in the tooth. On 25th July 1996 the Government announced that the BAe Nimrod 2000 had won the Replacement Maritime Patrol Aircraft (RMPA) contract with state-of-the-art systems and BMW 710 engines. However, this programme is running late, and first flight of what is now the Nimrod MRA Mk.4 is scheduled for 2004.

Carrier-Based Anti-Submarine

In 1945 preliminary discussions began for replacing the wartime Swordfish and Barracuda with an aircraft that would operate from escort carriers. The MoS was asked to prepare a specification to meet a Naval Staff requirement and this became GR.17/45 with OR.220. Westland responded with a twin-engined aeroplane but prototypes of both Blackburn and Fairey's proposals were first ordered in April 1946.

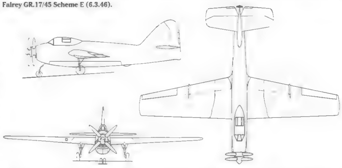


Fairey Type Q

Fairey's first GR.17/45 brochure was completed on 14th December 1945 and showed two designs, Schemes A and C. On 12th March 1946 a follow-up described Schemes D and E which differed principally from the first pair in having their wing area increased from 445ft² (41.4m²) to 475ft² (44.2m²). This allowed a full overload take-off in low wind speeds (around 21mph [34km/h]) to be effected with a run of 420ft (128m), while the approach speed with full strike load and two hours' fuel still aboard had been reduced to the extremely low figure of 76mph (122km/h). The improvements to D and E's low-speed performance were achieved at the cost of a very small reduction in top speed whilst a saving in fuel balanced the increase in structure weight from the bigger wing area; overload weights were 18,200lb (8,256kg) and 17,610lb (7,988kg) respectively.

Scheme D was powered by a single Rolls-Royce AP.25 double-propeller-turbine (later called the Tweed) and E by coupled twin Armstrong Siddeley Mamba turboprops. After about eighteen months of design work Rolls discontinued the Tweed so Fairey stayed with Armstrong Siddeley's engine which became the Double Mamba. Redesignated the Fairey

Fairey GR.17/45 Scheme E (6.3.46).



Above: **Hawker Siddeley Nimrod MR Mk.2 XV255 seen in its favourite environment. Built as an MR Mk.1, it was upgraded to Mk.2 standard with improved avionics.**

Right: **VR557 was the second Fairey Gannet prototype.**

17, the first prototype flew on 19th September 1949 and differed considerably from the early Type Q drawings; by October 1951 it had been named Gannet.

Blackburn B.54 (Y.A.5)

Blackburn's first GR.17/45 proposal was a development of the B.48 'Firecrest' torpedo bomber with a chin radome and powered by either an Armstrong Siddeley Python or Napier Double Naiad propeller-turbine with large diameter contra-rotating airscrews. A model was exhibited at the September 1948 Farnborough Show but again, as built, the B.54 would look quite different. Initially it was called the Y.A.5.

Comparing the two rival designs, Blackburn took the line of providing high engine power, either from a coupled Naiad or single Tweed, while accepting a fairly high wing loading. On the other hand, Fairey had proposed using a lower-powered engine, the twin Mamba, and had adopted a lower wing loading. On balance Fairey's scheme, thanks to its higher structure weight, came out about 500lb (227kg) heavier but neither design came within the all-up-weight requirement of 16,500lb (7,484kg). It was eventually agreed to raise the specified normal all-up-weight to 17,500lb (7,938kg) and in May 1948 the B.54's weight was expected to be 17,100lb (7,757kg).

By mid-1947 it was clear that the B.54 would be delayed and the coupled Naiad would be much later than first thought. It was therefore agreed to fit a Griffon engine in the first prototype, with an installation similar to the Shackleton's, to test its aerodynamics. A year later the estimated first flight of the Naiad machine had dropped back to December 1949 at the earliest so Blackburn proposed fitting a Double Mamba in the second aircraft to ensure that the company could have a turbine-propeller aeroplane flying at the same time as Fairey's. In the event the first two of three prototype B.54s flew with Griffons as the Blackburn Y.A.7 and Y.A.8 respectively, the first taking to the air on 20th September 1949, while the third aircraft flew with a Double Mamba on 19th July 1950 having been redesignated B.88 (SBAC designation Y.B.1). The aircraft's take-off performance with flaps down proved to be poor, which counted against it during official assessment.

Short S.B.3 Sturgeon

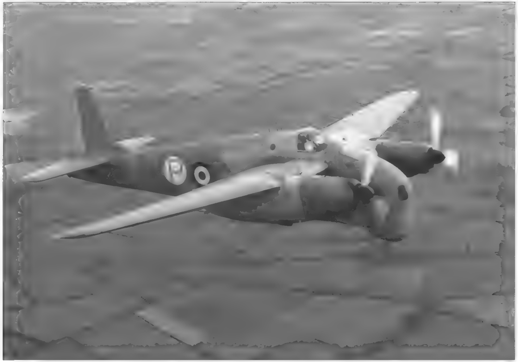
Around the end of 1947 it was stated that the need to operate from escort carriers was now unlikely, and soon afterwards the Staff requested that GR.17/45 should be a three-seater because its search radar needed a dedicated operator. Consequently, the entire situation was re-examined, GR.17/45 was upgraded and a third aeroplane came into the picture. This was an A/S version of the Short Sturgeon torpedo bomber suggested as a possible interim aircraft, although it would probably only be suitable to operate from large carriers. At an MoS conference of 8th March 1949 it was agreed to convert two Sturgeons from the production line as quickly and as cheaply as possible (in fact the last production airframe was turned into the first prototype while the second was begun from scratch). Specification M.6/49 and OR.275 were written around the project which was called the Short S.B.3.

It was soon obvious that the S.B.3 would not be ready soon enough to make it an interim type but there was a good case for building it to help develop the best equipment and tactical methods for finding and

Top: **WE488 was the third Fairey Gannet prototype and shows the retractable radome under the rear fuselage.**

Left: **Model of the original Blackburn Y.A.5 project with contra-rotating airscrews (6.6.46).** BAe Brough

Opposite page: **The sole Blackburn B.88/Y.B.1 prototype with Double Mamba powerplant. The second view was taken in September 1949.**



killing submarines, areas in which there was general ignorance. It could also be a long-term insurance against the complete failure of Blackburn and Fairey's aircraft. Most of the S.B.3 was similar to the Sturgeon Mk.2 target tug but the forward fuselage was extensively redesigned and bulged to accommodate a search radar under the floor and two Mamba turboprops replaced the original Merlin engines. However, there were delays due to an excessive number of design defects and also from Shorts' move from Rochester to Belfast, so the S.B.3 did not fly until 12th August 1950; early trials showed deficiencies in longitudinal and directional stability at slow speeds. The second machine was delayed by the non-delivery of its powerplants and, in fact, never flew at all because on 11th April 1951 it was decided that work on the S.B.3 should cease.

Competitive trials between the anti-submarine contenders were held in 1950. Initially the Fairey 17 was found to have some flight problems and, in regard to maintenance and accessibility, it compared unfavourably against Blackburn's machine. However, Fairey won the competition and 100 production Gannets were ordered to Specification GR.117P; there was no production order for Blackburn. The Gannet was now intended to replace A/S versions of the piston-engined Fairey Firefly developed since the war but the Double Mamba turboprop, designed so that the aircraft could cruise on half power only, incorporated many innovations. Its slow development resulted in a gap in the Navy's A/S capability and there was even a proposal in June 1950 to fit a Griffon 57 instead. In addition, the production Gannet had so many changes from the prototypes that it was virtually a new aircraft. Therefore, 100 Grumman Avengers were acquired from America as a stopgap and these began to arrive in Britain in March 1953.

The first production Gannet AS Mk.1 flew on 9th June 1953 and the type entered operational service in 1955. Eventually nearly 350 were built in six versions, including the very extensively redesigned AEW Mk.3 flown in 1958. Other developments considered but not built included another A/S version from June 1953, substantially the same as the Mk.1 but with ASV.20 radar, Blue Silk Doppler navigation equipment and the ability to carry a 3,300lb (1,497kg) Blue Boar type anti-submarine radar-homing bomb.

Lightweight Anti-Submarine

The GR.17/45 Gannet type would represent the backbone of the Navy's air anti-submarine forces and become the Service's standard A/S aircraft. It was large, expensive and fitted with comprehensive electronic equipment and was expected to be outstanding in its role, but it could only operate from carriers of the later light fleet size or above and not from escort carriers. A smaller, lightweight anti-submarine aircraft would be ideal to complement it and NR/A.32 with Specification M.123 was raised to cover this. This project, and the Gannet, broke with tradition because both were designed as dedicated anti-submarine aircraft when, previously, the job had been given to converted types such as the Fairey Firefly.

Blackburn B.83 and B.91

Blackburn's first project was the B.83 of July 1950 with a Rolls-Royce Merlin 35 piston engine, 250gal (1,137lit) of internal fuel, a bomb bay housing an A/S torpedo and underwing pylons for smaller weapons. Span was 45ft 0in (13.7m), length 41ft 7in (12.7m). In 1951 this was followed by the Mamba-powered B.91 for which no data survives but the aircraft is believed to have been similar in appearance to the Short Seamew. Blackburn did not tender to M.123 once the design team realised that a low wing loading would be undesirable in the turbulent conditions expected with rough seas, while using the powerful flaps needed to give sufficient high lift would make it very difficult to achieve adequate lateral control.

Short S.B.6 (P.D.4)

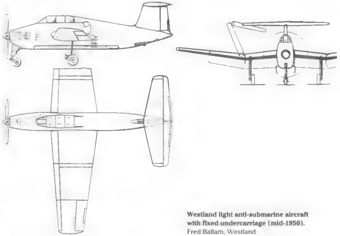
When first proposed in September 1950, this project had a tricycle undercarriage and three crew. The project proved to be the winning design but when built it had a tailwheel undercarriage and the crew had been reduced to two to cut fuselage size and weight.

Westland Light A/S aircraft

This project covered two designs, one with a retractable undercarriage, the other with fixed legs; wing, fin and T-tail were essentially the same but their fuselages differed somewhat as did the seating arrangements for the three crew. The Mamba could be replaced by a Rolls-Royce R.Da.3 Dart turboprop. Internal fuel totalled 270gal (1,228lit) and the homing torpedo was carried in a lower fuselage bay.

In October 1951 Fairey offered a cut-down Gannet with a single Mamba and a new nose; the rest of the aircraft was essentially unchanged. Fairey felt this conversion offered many advantages over an all-new design; one of the GR.17/45 prototypes could be converted which would save time and, since the aircraft differed only superficially from the original GR.17/45, its flight development programme would be much reduced. However, the Short S.B.6 was chosen and three prototypes were ordered in March 1952, the aircraft being named Seamew. It was felt that the Gannet was rather too elaborate an aircraft to equip RNVR A/S squadrons but the Seamew would be ideal since it would cost about half of the Gannet's price and be simple to operate and maintain. Australia and France were also potential customers.

The first Seamew flew on 23rd August 1953 and revealed some vicious handling characteristics but an initial batch of 41 aircraft was ordered in 1955 covering AS Mk.1s for the Navy and MR Mk.2s for RAF Coastal Command. A year later the RAF machines were cancelled and then the 1957 White Paper disbanded the RNVR's Air Branch altogether, cancelling the Seamew order with it. Twenty-four production machines had already flown and several had been accepted by the Royal Navy.



Westland light anti-submarine aircraft with fixed undercarriage (mid-1950). Fred Ballam, Westland

Right: **The first Short AS Mk.1 Seamew production aircraft, XE169, photographed during 1955.**

Opposite page: **Short S.B.3 WF632 seen during its first flight on 12th August 1950.** Short Bros.

Land-Based Maritime Patrol Aircraft Data

Project	Span ft in (m)	Length ft in (m)	Wing Area ft^2 (m^2)	All-Up-Weight lb (kg)	Powerplant Thrust lb (kN)	Max Speed Height mph (km/h) ft (m)	Weapon Load lb (kg)
Avro 696 Shackleton Mk.1 (flown)	120 0 (36 6)	77 6 (23 6)	1 421 (132.2)	86,000 (39,010) (Mk 2)	2 x Griffon 57 + 2 x Griffon 57A 2,450hp (1,827kW)	274 (441)	2 x 20mm cannon, large bay for A/S bombs, DCs and other stores
Avro 716 (at 4.50)	120 0 (36 6)	106 6 (32 5)	1,600 (148.8)	113,314 (51,399)	4 x Nomad N NM.3 3,000shp (2,237kW)	342 (550)	4 x 20mm cannon large bay for A/S bombs, DCs and other stores
Avro 719	132 0 (40 2)	102 8 (31.3)	1,615 (150 2)	114,693 (52,025) (Centaurus), 114,843 (52,093) (E.145)	4 x Centaurus 660 or Nomad E 145 (Nomad 3,050shp [2,274kW])	Centaurus, 324 (521) at 14,000 (4,267), E.145, 354 (570) at 13,000 (3 962)	6 x 20mm cannon, large bay for A/S bombs, DCs and other stores
Bristol Type 206	107 0 (32 6)	77 0 (23.5)	1,150 (107.0)	83,200 (37,740)	2 x Tyne R Ty 11 5,030shp (3,751kW) + 1,290lb (5.7kN) thrust	?	At least 6,000 (2,722) of stores in bay, 2 Bullpup ASMs under wings
Fairey NATO a/c	115 0 (35 1)	80 0 (24 4)	1,286 (119.6)	81,000 (36,742)	2 x Tyne R Ty 11 5,030shp (3,751kW) + 1,290lb (5 7kN) thrust	371 (597) at 20,000 (6,096)	Various stores in internal bomb bay
Avro 745	112 3 (34 2)	82 9 (25 2)	1,050 (97 7)	79,400 (36,016)	2 x Tyne R Ty 11 5,030shp (3,751kW) + 1 290lb (5 7kN) thrust	Cruise, 65,000lb mean weight 382 (615) at sea level, 397 (639) at optimum height	6 x DCs or 1,000 (454) mines, 10 x 1,000 (454), 21 x 500 (227) or 35 x 250 (113) bombs
Hawker Siddeley HS.801 Nimrod (flown)	114 10 (35.0)	126 9 (38.6)	2,121 (197.3)	178,000 (80,741)	4 x Spey 250 12,140lb (54.0kN)	582 (936) (max operating speed)	A/S torpedoes, mines, DCs and bombs

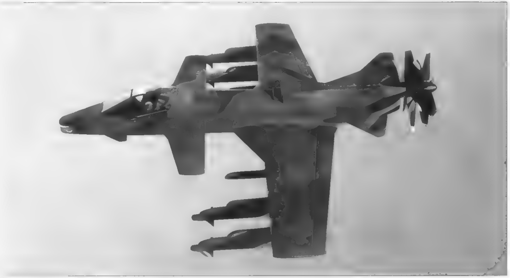
Carrier-Based Anti-Submarine Aircraft Data

Project	Span ft in (m)	Length ft in (m)	Wing Area ft^2 (m^2)	All-Up-Weight lb (kg)	Powerplant Thrust lb (kN)	Max Speed Height mph (km/h) ft (m)	Weapon Load lb (kg)
Fairey GR.17/45 (Schemes D & E)	55 0 (16.8)	43 0 (13.1)	475 (44 2)	D: 16,750 (7,598) E: 16,550 (7,507)	D. 1 x AP.25 2,500shp (1,864kW), E: 2 coupled Mamba	D 306 (492) at sea level, 316 (508) at 15,000 (4,572), E. 316 (508) at sea level, 305 (491) at 15,000 (4,572)	1 x A/S torpedo, 6 x DCs or bombs, 16 x RPs
Fairey Gannet AS Mk.1 (flown)	54 4 (16.6)	43 0 (13.1)	482 8 (44 9)	19,600 (8,891) take-off	1 Double Mamba 100 2,950ehp (2,200kW)	310 (499) at sea level	2 x 1,000 or 4 x 500 (227) bombs 2 x TTs, 6 x DCs, 1 x 2,000 (907) or 2 x 1,000 (454) mines
Blackburn B.88/Y.B.1 (flown)	44 2 (13.5)	42 8 (13.0)	?	13,091 (5,938)	1 Double Mamba 2,950ehp (2,200kW)	320 (515)	1 x A/S TT, 6 x DCs or bombs underwing RPs
Short S.B.3 (flown)	59 9 (18 2)	44 8 (13 6)	560 4 (52.1)	23,600 (10,705)	2 x Mamba 1,475shp (1,100kW)	c320 (515)	1 x A/S TT, 6 x DCs or bombs RPs

Lightweight Anti-Submarine Aircraft Data

Project	Span ft in (m)	Length ft in (m)	Wing Area ft^2 (m^2)	All-Up-Weight lb (kg)	Powerplant Thrust lb (kN)	Max Speed Height mph (km/h) ft (m)	Weapon Load lb (kg)
Short Seamew AS Mk.1 (flown)	55 0 (16.8)	41 0 (12.5)	585 (54 4)	14,400 (6,532)	1 x Mamba AS Ma 6 1,590shp (1,186kW)	235 (378) at sea level	Maximum 1,844 (836) of stores
Westland Light A/S aircraft	55 0 (16 8)	42 0 (12 8)	500 (46 5)	13,320 (6,042) (retractable u c), 13,240 (6,006) (fixed u c)	1 x Mamba AS Ma.3 1,320shp (984kW) or 1 x Dart R.Da.3 1,400shp (1,044kW)	?	1 x A/S torpedo or bombs, DCs

Variations on a Theme



Model of the P.1233-1.

This chapter covers items that were essentially peripheral to the general course of bomber developments. However, because they were studied in some detail, they demand deeper coverage than that normally addressed in Appendix 1.

Supermarine Scimitar

An entire chapter of the companion *British Secret Projects: Fighters* is devoted to the Supermarine Type 544 Scimitar but during the course of its service with the Fleet Air Arm, the de Havilland Sea Vixen took most of the Navy's interception duties leaving the Scimitar for bombing and strike operations. The main weapon for what was to become the aircraft's primary role was a tactical nuclear bomb to be delivered at low altitude but other work included ground attack with Bullpup ASMs, RPs or 1,000lb (454kg) bombs. It is not surprising, therefore, that there were several proposed developments dedicated to strike or bombing including two based on the Scimitar's ancestors, the Types 508 and 525.

Supermarine Type 522

In 1947 the Naval Staff raised a new requirement NR/A.19 for a single-seat strike aircraft. Various designs were considered to meet it, including a version of Fairey's N.40/46 all-weather fighter, before the Staff settled on a conversion of Supermarine's Type 508 day fighter to N.9/47. This project, the Type 522, had been requested by the MoS on 7th July 1948. There was to be minimal alteration to the 508's existing structure and twin 6,500lb (28.9kN) Avon installation with no change to the overall dimensions and no modifications to the wings and tail. Space was available in the lower fuselage between the engines for a weapon bay and removing the guns gave a bit more room. The bay was enclosed by doors which, when closed, formed a shallow blister on the fuselage underside forward of the wheel walls; a second 'bomb cell' aft of the wheel walls also formed a shallow blister.

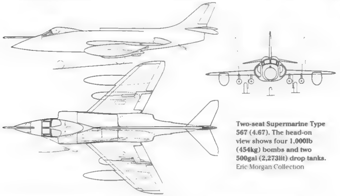
The 'bomb cells' were split because moving the main undercarriage would have resulted in major modifications. If large CofG shifts were to be avoided, a large weapon such as a 2,000lb (907kg) AP bomb had to be housed at or about the CofG. Unfortunately the 508's main wheels retracted into the fuselage just aft of the CofG and almost met on the centreline. The solution was to carry the 2,000lb bomb, or two 1,050lb (476kg) Red Angel rockets, externally under the wings in place of one of the drop tanks. Most of the other specified stores (two 1,000lb [454kg], four 500lb [226kg] bombs or various mines) would be carried internally but eight 60lb (27kg) RPs had to be carried externally and were loaded on to an underfuselage point just above the bomb bay door hinges. These arrangements were hampered by the fact that some established weapons were undergoing dimensional changes while the size of the newer weapons had not yet been frozen.

The performance requirements were severe, particularly the dive braking limits which would necessitate considerable modi-

fication to the 508's wings. The strike requirements had led to a heavier aircraft than the 508 which reduced the Type 522's manoeuvrability, but the level was still expected to be adequate. Internal fuel totalled 600gal (2,728lit) and the 522 could also carry two 200gal (909lit) external tanks. Sea level top speed with a clean aircraft was 622mph (1,000km/h), with drop tanks 535mph (862km/h); all-up-weight was 24,775lb (11,238kg). A reconnaissance role was also envisaged for this aircraft.

Supermarine Type 537

The Type 508 fighter was succeeded by an all-swept version called the Type 525 so the Naval Staff began to discuss a swept NR A.19 type (at this time the 525 was thought to be the aircraft that would go into service). A submission was requested on 10th January 1950 and the result was the Type 537 completed in April. This was a pure strike conversion of the Type 525 complete with swept V-tail (when flown, the 525 had a conventional tail) and the biggest change was a long ventral bulge beneath the fuselage stretching from the rear cockpit to just ahead of the tail. This single 'bomb cell' replaced the 522's separate cells and housed all of the weapons internally except for the 60lb RP pylons placed to the sides of the fuselage (the weapons were unchanged from the 522). Sea level top speed 'clean' was 678mph (1,091km/h), with drop tanks 570mph (917km/h); all-up-weight was 23,950lb (10,864kg), overload was 27,830lb (12,624kg). The wings and tail had more area than the 522; span was 37ft 6in (11.4m) and length 54ft (16.5m). Plans to build prototypes of the 537 were suspended on 18th April 1950 because of a lack of money.



Two-seat Supermarine Type 567 (4.67). The head-on view shows four 1,000lb (454kg) bombs and two 500gal (2,273lit) drop tanks. Eric Morgan Collection

Supermarine Type 561

The Type 561 was planned as a de-navalised Scimitar adapted for the RAF as a low-level nuclear bomber. It was discussed through summer 1956 and received much interest from the Air Staff as an interim type. One tactical nuclear bomb would be carried and the Type 561 would cruise to its target at high subsonic speed and low level, but successful navigation at low level without a second crewman was thought to be a difficult problem to overcome.

Supermarine Type 562 and 564

Work on the Type 562 with interceptor and strike capability began in January 1956 and brochures were sent to the MoS in mid-July. Supermarine claimed that deliveries could start in 1959 directly after Scimitar production was completed. Discussions centred on what air-to-air missiles would be carried. With AI.23 radar and two Blue Jay AAMs top speed would be 737mph (1,186km/h) at sea level, 647mph (1,041km/h) at 40,000ft (12,192m); sea level rate of climb was 21,100ft/min (6,431m/min) and all-up-weight 34,799lb (15,785kg). Initially, all-up-weight with one TMB was 40,990lb (18,593kg) but a revised strike version called the Type 564 was offered on 10th February 1957 with Avon RA.24s or de Havilland Gyron Juniors. Now, with one TMB, one 200gal (909lit) and two 500gal (2,273lit) drop tanks, respective weights with these engines were 47,438lb (21,518kg) and 48,764lb (22,119kg). The smaller Gyron Juniors allowed extra fuel to fill the space they saved while 'blow' would be extended across half of the ailerons. Work on the project appears to have ceased in March 1957.

Supermarine Type 567

The Naval Staff had forecast a gap between the Westland Wyvern strike fighter's retirement in 1957/58 and the Buccaneer's introduction in 1961/62 and the NR/A.19 type was thought to be the most suited to fill it. The result was the single and two-seat Type 567 of April 1957, prepared to and expected to meet the major items of the M.148 (Buccaneer) requirement; the two-seater appears to have been the more important. (At this time Scimitar itself had completed over 400 hours flying on three prototypes and six production machines.) The main differences from Scimitar, other than two seats and M.148 equipment, were deletion of guns, provision of part-span aileron blowing, increased internal fuel from 1,064gal (4,838lit) to 1,374gal (6,247lit), strengthened wings and an extra store station near each wing root. In zero wind a radius of 420nm (778km) was possible at a 42,000lb (19,051kg) take-off weight but flight refuelling would push this up to 915nm (1,695km). The two-seater's span was 37ft 2in (11.3m), length 61ft 10.5in (18.9m); all-up-weight with one TMB, one 200gal (909lit) and two 500gal (2,273lit) tanks was 50,220lb (22,780kg); with four 1,000lb bombs and two 500gal tanks, 50,460lb (22,889kg). Work continued through the year and wing tip tanks were suggested in October to improve range.

Bombed-up Scimitar F Mk.1 XD242 of No 803 Squadron aboard HMS *Victorious* around September 1958. Lee Howard Collection

Supermarine Type 576

This supersonic Scimitar was first proposed on 5th December 1958 as a strike aircraft and its bulkier fuselage, which housed dorsal fuel tanks, brought a substantial change in appearance. The RA.24 Avons were replaced by non-reheated 13,220lb (58.8kN) RB.146s and a single-seat version had more fuel and extra pylons to give either a six 1,000lb (454kg) external load or four bombs with two tanks. A Ferranti Airpass I search radar, as fitted to the Lightning, gave a ship search facility of 60nm (111km) and provided a much closer approach to all-weather capability in both strike and fighter roles. The extension of 'blow' or 'supercirculation' over the outer as well as the inner wing reduced the catapult wind requirement by about 9mph (14.5km/h). With these improvements, maximum strike radius in M.148's low attack sortie with a TMB at 47,425lb (21,512kg) weight was 665nm (1,232km). Span was 37ft 2in (11.3m), length 61ft 0in (18.6m).

A two-seater was intended to meet M.148 more closely. The dorsal tanks held 600gal (2,728lit) of fuel while fuselage tankage was increased by another 302gal (1,373lit) and a further two 1,000lb bombs were housed internally so that six bombs could be carried in addition to the nacelle tanks. Strike radius with the TMB was 788nm (1,459km) and a typical launch weight was 53,000lb (24,041kg). This aircraft was intended to be available for delivery to service in 1962. (Type 576 fighter developments are covered in *British Secret Projects: Fighters*.)

Further proposals made on 15th April 1959 indicated a host of possible retrospective modifications to current Scimitar airframes to convert them to supersonic Type 576 standards (with lower development costs than would be expected for a completely new aircraft design). In summary, the improvements offered by the Type 576 over the current Scimitar were the removal of the limitation to fair weather operations in both strike and fighter roles, twice the effective strike radius and, when the Red Top AAM was available, the ability to attack targets flying at Mach 2 and 65,000ft (19,812m).

Unmanned Flying Bombs

In September 1945, with memories of the German V1 flying bombs still fresh, the Air Staff requested an unmanned expendable bomber that would offer a greater range than was practicable for conventional aircraft. Subsequently the Expendable Bomber Working Party was formed under J E Serby's chairmanship to examine the subject and in September 1950 it reported that such a type, radio-controlled from Great Britain with a 400nm (741km) range, was feasible and a worthwhile proposition. In the event of an enemy occupying the Channel coast, the weapon could help protect the UK from short-range air attack and act as a counter offensive to neutralise enemy air strength through the accurate attack of his airfields. Other targets might include missile launch sites, troop concentrations, communications centres, industrials plants, bridges and radars.

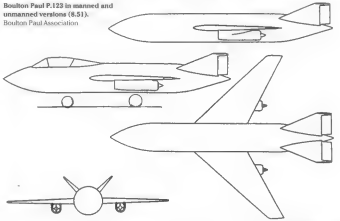
UB.109T (and OR.1097)

On 18th December 1950 OR.1097 and UB.109T for a Short-Range Expendable Bomber were issued and, in April 1951, Boulton Paul, Bristol and Vickers were invited to submit tender design studies. Only limited discussion with TRE was permitted and designers were specifically requested to refrain from making any approach to the radio industry. The required warload was a cluster of ten 500lb (227kg) bombs (using, if possible, current bomb stocks) and a range of 250nm (463km) from ground stations was requested with a still air fuel range of 400nm (741km). Speed had to be 500 knots (576mph/926km/h), height 45,000ft (13,716m) and an accuracy of 250 yards (227m) was needed with a handling rate (by the guidance system) of 60 bombers per hour. Launch would be from a slotted tube catapult operated by cordite.

It was thought that unit production could possibly reach many thousands since it was intended to launch the weapon in barrages. The company's studies were completed in August and September 1951 although Bristol's initial work had begun in 1949 and Vickers' in the first half of 1950. It was intended to order prototypes for detail design and construction and to further explore the concept. During early 1952 the weapon was called Red Rapier and it was expected to take its place in Britain's defences between 1958 and 1962.

Boulton Paul P.123

This had a swept wing with no ailerons, a V-tail with combined elevators/rudders and two 1,750lb (7.8kN) RB.93 jets in underwing pods.



Boulton Paul P.123 in manned and unmanned versions (8.51). Boulton Paul Association

Two versions were planned: an unmanned blast variant with 2,000lb (907kg) charges housed in both the forward and rear fuselage which would detonate together at the end of a 900mph (1,448km/h) dive, or a manned type which would carry and release eight 500lb (227kg) bombs in the conventional way. Launch would be from a rocket-propelled trolley on a track. Span was 21ft (6.4m), length 30ft 3in (9.2m), wing area 110ft^2 (10.2m^2), all-up-weight 9,300lb (4,218kg) and top speed 593mph (954km/h) at 40,000ft (12,192m). In December 1951 Boulton Paul told the Air Ministry that it did not intend to undertake any production.

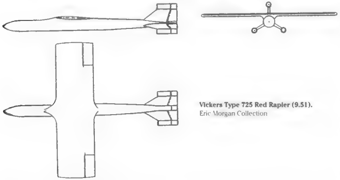
Bristol 182

This project was to be built in moulded Durestos (asbestos fibre, phenol and formaldehyde resin – the same material used for Bristol's plastic drop tanks) which was found to be lighter and cheaper to produce than steel. Type 182's fixed wing had a shape identical to that of the Folland Gnat and there was no undercarriage since a launch would be made from a ramp using a cordite cartridge. A 3,750lb (16.7kN) Bristol BE.19 jet would be used on production machines but retrievable prototype Type 182Rs were suggested powered by an Armstrong Siddeley Viper. The 182R would be built of light alloy and have a variable incidence wing and a de Havilland Venom fighter undercarriage. Type 182's span was 20ft 10in (6.3m), length 33ft 10in (10.3m), wing area 145ft^2 (13.5m^2), all-up-weight 9,350lb (4,241kg) and top speed 576mph (926km/h) at 41,000ft (12,497m).

Vickers Type 725

Vickers also called this the SP.2. It would be easy and cheap to produce using well-known techniques in a structure of welded mild steel angle and sheet. It avoided tapered and swept aerodynamic surfaces and used three 1,750lb (7.8kN) RB.93s grouped on 'fins' around the rear fuselage; launch would be from a ramp using compressed air. Over the target the engines would be stopped before the machine was zoomed to lose speed, it would then bunt over into a vertical dive, speed being limited by a tail parachute. Span was 32ft (9.75m), length 45ft 5in (13.8m), wing area 212ft^2 (19.7m^2), all-up-weight 12,000lb (5,443kg) and top speed 547mph (880km/h) at 51,500ft (15,697m).

The Bristol Type 182R prototype seen at Filton on 18th July 1953 before completion. The wing/body fairing and engine pylon and pod are still not in place. Note the deployed airbrake. Jim Oughton Collection



Vickers Type 725 Red Rapier (9.51). Eric Morgan Collection

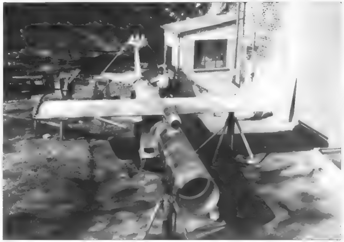
The biggest hindrance to the swift production of an expendable bomber was the lack of available electronic R&D effort in the UK to develop a precision guidance system of the required accuracy and high handling capacity. For this reason attempts were made to enlist Australian aid, but they were prepared to participate only if they were given complete responsibility with no corresponding effort in Britain. However, it was intended that production should take place in the UK with the testing done in Australia. The only guidance system already developed which could be used immediately was the wartime Oboe and in January 1952 the Air Staff accepted this system's low handling capacity in order to get Red Rapier active as soon as possible. Some of the old wartime ground stations were still available for use in development trials.

Red Rapier was approved in principle in November 1951, provided it did not interfere with other important projects. However, development contracts for Bristol and Vickers were held back in March 1952, despite both companies having already spent considerable sums on their projects, because the negotiations to bring the Australians into full or partial development had done much to fog the situation (Bristol had begun to build two 182R airframes as a private venture). On 9th April it was agreed that the two projects should proceed, although dropping Vickers had been considered in January to save money. The American B-61 Matador surface-to-surface tactical missile was also compared against OR.1097 but proved unsatisfactory.

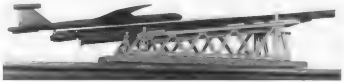
Most of the test flying would be done at Woomera, Vickers using 12 wooden one-third scale models (Type 719) released from a piston bomber and 12 full-scale Type 725s. Trials would begin in early and late 1953 respectively but these dates slipped and the first 719 gliding flight was not made until 8th August 1953, at which point the full-scale 725 was expected to fly in Australia in 1955. Bristol planned to do all of its development work using 11 recoverable 182Rs and 18 expendable 182s, the first flying from Woodbridge. The title Red Rapier embraced both Bristol and Vickers projects.

Blue Rapier was to be an expendable decoy aircraft with a range and performance similar to the V-bombers. It was to be based on Red Rapier with the 5,000lb (2,268kg) warload replaced by 4,000lb (1,814kg) of fuel and 1,000lb (454kg) of ECM equipment. Work had still to begin in July 1954 when suggestions were made for a supersonic Red Rapier. Two months later Red Rapier's suitability as a Staff Target was re-examined and the Air Staff concluded that its development should not continue. Manned bombers with stand-off weapons would be better and the project was cancelled on 30th September 1954. The first Bristol Type 182R was nearing completion in mid-1953, although the powerplant and autopilot had not been installed, and the second was well advanced. It is believed that no full-scale Vickers 725 was completed although a fuselage was rig tested in 1954.

Besides the problem of accurate guidance, there were concerns about how effective these systems might be. They would be vulnerable to interference and, as their attack range was increased, the time for effective enemy countermeasures would also increase which meant that the attack's accuracy could be reduced. The accuracy of attack would only have to fall to half that of a conventional bomber for four times the weight of unmanned attack to be required. The accuracy of attack from a conventional bomber using visual weapon-sighting, or devices independent of ground aids, was more consistent and did not lessen with increases in range. In addition, the unmanned bomber's targets would be limited to those which were static for quite long periods, so Red Rapier could only fulfil a small part of the short-range bomber task. Today we would call Red Rapier a cruise missile.



A full-size Vickers Red Rapier seen at Foxwarren on 27th September 1954. Eric Morgan Collection



Model of the Vickers Red Rapier on its launch ramp, an inclined cylinder arrangement similar to that used for the wartime V1 flying bombs. Eric Morgan Collection

NATO Light Strike

In 1954 NATO formulated a requirement for a daylight ground attack type with the ability to also perform as a fighter. It called for Mach 0.95 at low altitudes, carriage of two 500lb (227kg) bombs and 12 3in (7.6cm) RPs and the ability to take-off from a grass strip. Emphasis was placed on simplicity because the increasing complexity of modern combat aircraft was causing concern. Contenders included Italy's Fiat G.91, the Breguet Br 1001, Dassault Mystère XXVI (alias the Etendard VI) and Sud-Ouest SO 6150 from France, and the Avro 727 and a version of the Folland Gnat fighter from Britain. Several of the competitors were built and the G.91 was chosen as the winner in January 1958. It went on to serve with both the Italian and West German air forces.

Avro 727

When first drawn in January 1954 this was essentially the Avro 726 fighter powered by an 8,000lb (35.6kN) unreheated jet and fitted to carry RPs or two 1,000lb (454kg) bombs; the 726 itself was a supersonic jet-powered version of the 720 rocket fighter. By April, when work began on the NATO study, the aircraft had changed and side intakes and a higher wing had been introduced. Power came from a single Bristol BE.26 Orpheus jet of 3,750lb (16.7kN) sea level static thrust, but eventually this figure was to be increased to 4,850lb (21.6kN). Armament was two 30mm Aden cannon or four 0.5in (12.7mm) Browning guns in the lower front fuselage plus 12 3in (7.6cm) air-to-ground rockets; alternatively, two 500lb (227kg) or 1,000lb bombs or two napalm tanks could be carried with the guns. All-up-weight with RPs and Adens was 10,086lb (4,575kg), increasing to 10,214lb

(4,633kg) with the extra power; rather more than the desired 8,000lb (3,629kg), but Avro stated that this would not affect the aircraft's handling or operation from poor surfaces. The extra size meant there was also great development potential within the design.

The 727 used, with minor modifications, the same wing as the 720 and Avro felt that this configuration offered an 'unequalled combination of flying qualities'. A low wing loading, the stiff wing and the large, power-operated elevons gave great manoeuvrability at both high and low speeds while the thin, highly swept wing postponed the effects of compressibility. No adverse behaviour was expected over the speed range up to Mach 1.0. Except for its fuselage, the 727's aerodynamic configuration was the same as the Avro 720's so its behaviour should have been proved before it flew (in fact the Avro 720 was cancelled in 1955 before completion). Its structure consisted mainly of metal honeycomb sandwich.

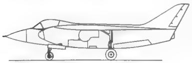
After delivering its ground ordnance, the 727 could switch to its fighter role. With the low power rating, RPs and Adens, top speed 'clean' was Mach 0.95, when carrying rockets Mach 0.89, sea level rate of climb 6,000ft/min (1,829m/min) and service ceiling 40,000ft (12,192m); with the extra power these figures became Mach 0.92, Mach 0.97, 9,100ft/min (2,774m/min) and 46,000ft (14,021m) respectively. Internal fuel was 360gal (1,637lit), span 27ft 4in (8.3m), length 35ft 9½in (10.9m) and wing area about 360ft² (33.5m²).

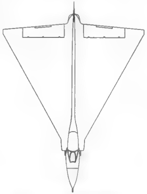
BAe Kingston SABA

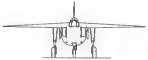
This presents something of an oddity since the SABA (Small Agile Battlefield Aircraft) does not really fit into the category of either bomber or fighter. Judged solely on weapon load (AAMs, no bombs) it could be classified as a fighter but, because it was designed to destroy helicopters, tilt-rotor aircraft and ground targets such as tanks and trucks, it perhaps fits more comfortably in a bomber book. It certainly was not intended to tangle with fighters and the concept really needed air superiority to make it work.

By the 1980s a number of new threats had begun to emerge, particularly in Europe, which included heavily armed high-performance helicopters, unmanned air vehicles, tilt-rotor aircraft and very mobile ground forces. It appeared to BAe that no suitable air counter was available to assist thinly spread friendly ground forces threatened by such opposition. The principal needs for an effective battlefield counter-air and ground forces suppression aircraft would include low cost, low vulnerability, very high agility, carefree handling, soft field operation, long endurance and all-weather day and night operation. The key markets were seen to be NATO Europe and the US Army (in autumn 1986 the latter had solicited US industry proposals for an 'Advanced Counter-Air Fighter' optimised for the anti-helicopter role).

SABA possessed outstanding agility and turn performance to allow it to take out enemy attack helicopters. Its rate of turn was intended to be 180° in five seconds, which was considered essential to guarantee a kill opportunity against nap-of-the-earth targets, with maximum turn radius 410ft (125m) at combat speeds. Current 'extremely agile' combat aircraft had lower turn rates which they achieved at high speeds and large radius owing to their high wing loadings. Maximum speed was intended to be 460mph to 520mph (741km/h to 837km/h) to enable it to make a rapid transit to threatened areas at very low altitude while also enhancing its survivability in a dash across the battle zone. SABA could loiter with AAMs and a gun at low level over the battle area for at least four hours, the number of weapons reflecting the fact that its targets usually operated in substantial groups.







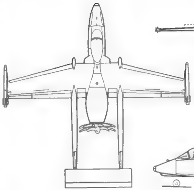
Avro 727 in its final form of September 1954, though it differs little from when first designed to NATO's requirements the previous April. Avro Heritage Centre

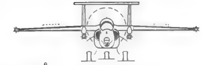
Impression of the Avro 727. Avro Heritage Centre

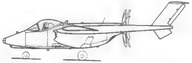
This concept was essentially a BAe private venture and came together in a combined brochure during May 1987; several configurations were studied. Meeting the agility limits demanded an aircraft with good lift drag ratio in the high-lift condition while a variety of powerplants were considered ranging from propfans, offering exceptional fuel economy and high static thrust, to low-bypass turbofans which had a superior dash performance.

BAe P.1238

A twin-tailboom pusher type, intended to have simple systems and manual control, armed with six ASRAAMs mounted at the wing tips and on the booms and one fuselage-mounted 25mm cannon. This was the low-technology approach which used a 4,502hp (3,357kW) Avco Lycoming T-55 propfan. Span 36ft (11.0m), length 37ft 11in (11.6m), wing area 200ft² (18.6m²), maximum take-off weight 11,098lb (5,034kg).



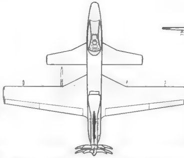


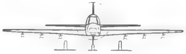


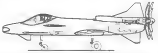
BAe P.1238 (5.87). Brooklands Museum

BAe P.1233-1

This was considered to be a 'state-of-the-art' approach. An aft T-55 pusher propfan could provide directional stability but it would reduce the effectiveness from a rear-mounted rudder, so a nose rudder was fitted instead. The canard enhanced manoeuvrability since the foreplane load required to increase angle of attack acted in the same direction as the wing lift. Obtaining the best performance from the combination of wing and foreplane, with flaps on the former, while avoiding departure in manoeuvres, would be helped by a fly-by-wire control system in pitch. Six ASRAAMs were pylon mounted. Span 36ft (11.0m), length 31ft 4in (9.5m), wing area 219ft² (20.4m²), maximum take-off weight 11,000lb (4,989kg).







BAe P.1233-1 (5.87). Brooklands Museum

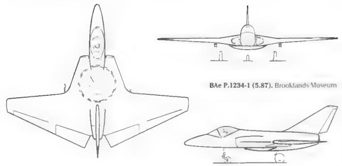
BAe P.1234

This covered three separate projects:

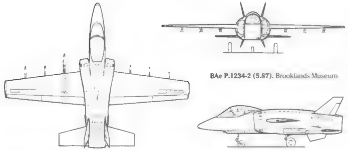
P.1234-1

A novel idea schemed to investigate the integration of a gun turret into a manoeuvrable aircraft; the combination of a helmet-mounted sight and a powerful cannon with a wide field of fire offered great flexibility against targets of opportunity. The large turret dictated a blended-body wing and a 5,715lb (25.4kN) Rolls-Royce Adour RT-172-871 powered the aircraft, the low bypass ratio minimising intake size. Two ASRAAMs were carried for self defence and static instability and active controls were essential to obtain

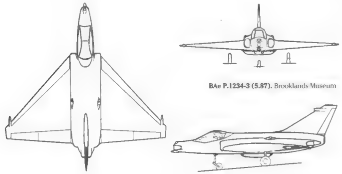
Impression of the P.1233-1. Brooklands Museum



BAe P.1234-1 (5.87). Brooklands Museum



BAe P.1234-2 (5.87). Brooklands Museum



BAe P.1234-3 (5.87). Brooklands Museum

maximum manoeuvring from the large wing. Span 36ft (11.0m), length 31ft 6in (9.6m), wing area 387ft^2 (36.0m^2), maximum take-off weight 12,685lb (5,754kg).

P.1234-2
To compare the constraints of propfan and turbofan layouts, P.1234-2 was drawn with a 7,515lb (33.4kN) Avco Lycoming ALF.502, which essentially used the T-55 as its core. Wing geometry was equivalent to the P.1233-1 and P.1238 and full-span flaperons and spoilers were suggested for low-speed roll control. To maximise manoeuvrability, P.1234-2 needed static longitudinal instability and active controls but, with some performance penalty, simple manual controls could be used instead. The engine installation markedly compromised fuselage design and the intake duct dominated the layout. Armament was the same as the P.1233-1. Span 36ft, length 29ft 8in (9.0m), wing area 200ft^2 (18.6m^2), maximum take-off weight 12,396lb (5,623kg).

P.1234-3
An alternative to the P.1234-1's gun system shortcomings was a guided hypervelocity missile system. The twin-tube launcher could rotate to allow a launch at any angle to the aircraft's direction of flight, the extraordinary acceleration of a hypervelocity missile preventing appreciable disturbance. Reloads were contained in a feed mechanism in the fuselage and 12 rounds were carried. To gain the full benefit of the missile's destructive power, a highly capable acquisition, tracking and engagement system was needed with its optical or infra-red components contained in seeker turrets in the nose and on either side of the rear wing root fairing; further infra-red and radar receivers were placed around the airframe. Combining the launch turret's 360° azimuth coverage with a high rate of roll allowed the pilot to engage targets in any position within range and this freedom reduced the need for extreme aircraft agility. Fly-by-wire was essential and the Adour installation was similar to the P.1234-1. A 12.7mm machine gun was available to attack targets for which missiles were unsuitable or wasteful. Span 30ft (9.1m), length 31ft 3in (9.5m), wing area 331ft^2 (30.7m^2), maximum take-off weight 12,747lb (5,782kg).

SABA was produced at a time when aircraft companies were seeking new markets and it appeared that the canard propfan P.1233 would meet the requirements. Some felt that the NATO market was potentially massive but as a whole, British Aerospace was doubtful about the idea. In the event, the SABA did not progress much further than this brochure.

Chapter Thirteen

Strike Trainers

A four ship sortie of SEPECAT Jaguar Mk.1 aircraft from 6 Squadron RAF Coltishall. Offensive stores include laser-guided and 1,000lb (454kg) bombs while Sidewinder AAMs are carried for defence. North West Heritage Group

Background to Jaguar: 1962 to 1970

In 1960 the RAF held the view that a supersonic advanced trainer was unnecessary as a lead-in to contemporary supersonic fighters like the English Electric Lightning. The USAF disagreed and adopted the Northrop T-38 as its advanced trainer but the capability of this aircraft to fly at Mach 1.3 made it expensive. Some European air forces felt that costs could be reduced by eliminating the advanced trainer altogether, so that the pupil passed directly from his basic trainer to a dual version of an operational aircraft. But the gap between the two types was really too wide and a two-seat operational aircraft was far more expensive to buy and operate than an advanced trainer. The solution was an advanced trainer which could also be marketed as a front-line light strike export aircraft for those countries that could not afford a more sophisticated bomber. Several manufacturers examined this idea, which was eventually to lead to one of the RAF's most successful attack aircraft, Jaguar.

Folland Fo.147
In October 1960 Folland proposed, as a successor to the Gnat advanced trainer, a single-engined variable geometry trainer called the Fo.146 and in January 1962 followed it up with an armed version using two RB.153 engines. Between the two versions came the Fo.147 swing-wing aircraft designed to demonstrate the proposed uses of VG in the air, which Folland thought needed to be done using an operational aircraft and not merely a 'flying model'. The company had long felt there was a requirement for a comparatively small supersonic (Mach 2+) aircraft in the interceptor and ground attack class and had proposed the twin-engine Gnat Mk.5 as just such a type.

The brochure suggested that applying VG to such a simple and inexpensive aircraft as the Gnat Mk.5 could push top speed up by 50% to Mach 3 and, while retaining the Gnat Mk.1's low-speed performance, also give a higher ceiling and greater radius of action and military load. The Fo.147 was based on the Gnat Mk.5 fighter-trainer and would use wing sweep between 0° and 25° for low speeds, where maximum use could be made of high-lift devices, and sweep angles between 60° to 70° for flight at Mach 2+. Two reheated RB.153s were used, initially limited to Mach 2.2, internal fuel capacity was 610gal (2,774lit) and design diving speed 835mph (1,343km/h) EAS. The main proposal had a rotating retractable foreplane and no tail but an alternative dispensed with the foreplane and introduced tail surfaces and modified wing tips.

Folland Fo.148
This work came together in May 1962 as the Fo.148 advanced supersonic weapons and operations trainer and strike aircraft, which was intended for use in three forms. Firstly, it could be produced as a primary trainer operating with its VG wings fixed forward and without radar; Stage 2 (which would replace the Gnat trainer) had VG wings but no operational equipment or reheat; Stage 3 would

include the full range of wing sweep, a reheated engine, nose radar and full equipment. Hence, one basic airframe could perform primary, advanced and operational training and also be comfortably afforded by overseas countries (it was the export version that was intended to undertake any attack operations).

Developed from the Gnat Mk.1 trainer, Fo.148 had a single reheated RB.153-61 bypass engine fitted with a thrust reverser to reduce its landing run. It could fly as a tactical ground attack trainer or interceptor and carry the navigation and fire control equipment used in the TSR.2, Buccaneer or Lightning (all of these aircraft used variants of the same Ferranti search and weapon-aiming radar). The VG mechanism comprised a neat fuselage-mounted 'pivot and shoe' arrangement without any retracting parts in front of the wing, which itself had full-span leading-edge flaps and slotted trailing-edge flaps. Stores, including Bullpup ASMs or Red Top AAMs, could be carried on two pylons fixed to the side of the fuselage level with the main wheels. Ceiling was 60,000ft (18,288m), radius of action as a trainer 330nm (611m), as an interceptor 200nm (371km), as a strike aircraft on a high-altitude mission 255nm (473km) and on a low-altitude sortie 180nm (334km). The Fo.148 may have been a sensible idea and was expected to fly in 1963 64 but it never happened. It was the last Folland designation to be used after the company joined Hawker Siddeley in 1960.

BAC (Vickers) Type 593

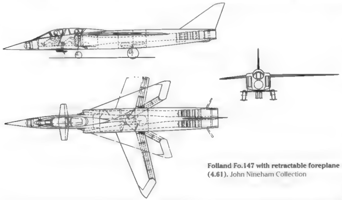
In April 1964 BAC Weybridge proposed the experimental Type 593 to confirm by flight test the company's claims for, and solve the problems posed by, variable sweep; it would also determine the handling characteristics and drag of a VG aircraft. In the absence of any immediate military or civil requirement, the 593 would be the next step forward after the company's many years of VG study and it would keep together and maintain the skills of a design team which had acquired so much VG knowledge. In Chief Designer Alan Clifton's opinion, 'much valuable time had already been lost in the argument associated with settling a service type' (in recent years his company had made six variable sweep proposals). Minimum cost was a primary aim so the 593 would use, for example, current production engines.

This aircraft would be the founder member and a scale model for a family of possible military VG types up to about 80,000lb (36,288kg) weight. Both twin and single-engined versions were drawn, the bulk of the study and information devoted to the former (Aircraft A) but performance, weight and cost variations were given for a single-engine Aircraft B. Both were single-seaters offering variable sweep between 25° and 65°. Structural design was conventional using aluminium and steel and the wing would pivot at the side of the fuselage on a single pin, this simple mounting having already been tested on the Type 999 variable sweep test specimen (a ground-based test apparatus, not an aircraft) but with the difference that all bending moments and shear were reacted by the pin alone. The wings had ailerons at the tip and a split trailing-edge flap, there was an all-moving tail and the undercarriage essentially came from the Folland Gnat.

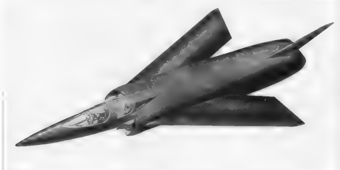
The powerplant was served by fixed semi-circular intakes with a fixed cone. Type 593A used the American General Electric J85 which was the only production unit available of a size suitable for a twin-engine layout of supersonic capability; B had an RB.153-61 which, at the time, was in limited production against a German requirement. The RB.145 had been considered for Aircraft A but this was a heavier engine of slightly less thrust. Aircraft A was thrust-limited to Mach 1.6, B structure-limited to Mach 1.75 and their maximum time at Mach 1.6 was 5.2 and 15.0 minutes respectively. Both carried 3,000lb (1,361kg) of internal fuel and 400lb (181kg) of instrumentation. First flight would be in about 1967.

At the same time the Weybridge Military Project Office was helping BAC Warton's Project Office with AST.362 (below). Three families of aircraft were being studied to this requirement and they embraced numerous designs fitted with and without reheat:

a. Variable sweep aircraft with two engines.
b. Variable sweep aircraft with a single engine.
c. Fixed-wing aircraft with two and one engines.



Folland Fo.147 with retractable foreplane (4.61). John Nineham Collection



An impression of Fo.147 with its wings swept back. John Nineham Collection

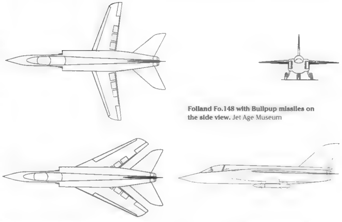
Item b) used an RB.168 and was the variant examined by Weybridge. This work was covered by Warton's P.45 designation, which appears to have overtaken the Type 593, and picks up the story of British VG development left off in Chapter Nine.

AST.362

In June 1963 the Air Staff began studying a new advanced pilot trainer to AST.362 to replace the Gnat/Hunter sequence. This would be used for preliminary conversion training and squadron continuation training, together with a secondary minor operational role. By the end of the year the final draft was specifying a target date of 1975 but the document was put on hold after a similar requirement appeared in France in February 1964. The British and French Staffs then discussed their respective needs and a combined Anglo-French provisional requirement was produced and issued by the MoA to British industry in March. This noted that the Royal Navy, RAF and French Air Force needed a dual-purpose advanced two-seat pilot training light strike aircraft. Although the French were more interested in the operational aspects of the aircraft when British interest centred on the training side, the two requirements could be compatible. A joint project would lead to material savings in cost and effort in both countries while providing a more useful aircraft all-round, which might also prove attractive to other air forces.

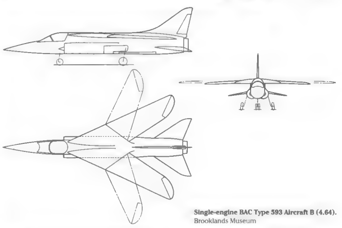
In-depth discussions over a possible joint project began two months later. Early problems centred on a difference in weight, French industry's assessment of an aeroplane to meet its home requirements only being much lighter than the MoA's figure for a combined type. The French Air Staff primarily required fairly large numbers of an inexpensive light tactical strike aircraft with first-class low-level capability but, although secondary in importance, its advanced pilot and crew trainer had to be the first version delivered (by 1970). The British side wanted its advanced trainer to be supersonic at altitude but also suitable for low-level training; a strike/recce version was a secondary requirement.

During the summer of 1964, studies using AST.362 as a basis were undertaken by BAC and HSA which drew on previous trainer proposals and their research into variable sweep and vectored thrust respectively. The aircraft assessed were two twin-engine versions of BAC Warton's P.45, one with a VG wing, the other with a delta wing and elevon tailplane derived aerodynamically from TSR.2 (but with wing loading reduced to suit the AST),

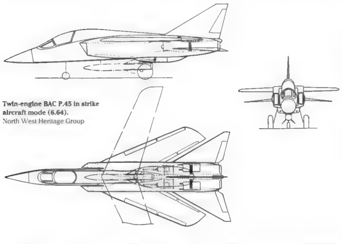


Folland Fo.148 with Bullpup missiles on the side view. Jet Age Museum

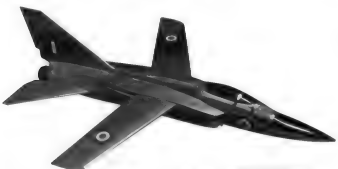
Model of the Fo.148. Philip Norman Collection



Single-engine BAC Type 593 Aircraft B (4.64). Brooklands Museum



Twin-engine BAC P.45 in strike aircraft mode (6.64). North West Heritage Group



One version of the BAC P.45. BAE Systems

and the supersonic single-engine Hawker Siddeley HS.1170B with deflected thrust and plenum chamber burning (PCB).

BAC (English Electric) P.45

The VG version's wings pivoted about vertical hinge-pins built into the fuselage sides and could be swept from 25° for economic subsonic cruise and good airfield performance to 68° for high-altitude supersonic flight and high subsonic flight near the ground. Full-span Fowler flaps and leading-edge slats were incorporated to take full advantage of the low sweep angle during take-off and landing. An all-moving tailplane was fitted, fuel was housed in the wing and fuselage and the intakes were of a fixed ramp, single wedge type; reheat would be used for take-off and supersonic flight only. Except for the wing, the non-VG version was virtually identical and used the same engine (the small bypass RB.172). Part-span blown flaps were fitted for high lift but the 58° fixed swept wing carried no controls.

BAC had recognised that the UK was now behind the USA (with its F-111) in the practical development of the variable sweep technique first proposed in Britain. Hence, the brochure advocated the immediate design and construction of some prototypes of the P.45 with a full experimental flight trials programme. The project was seen as a multi-role VG aircraft capable of acting as an advanced trainer, an air defence fighter (with particular application for overseas duties), and a light strike and recce aircraft. Low cost was a big attraction but the company's investigations had also shown the type to be very effective in the air-to-air role when compared to air defence systems of much greater maximum weights. Normal all-up-weight was about half that of the Type 583 strike fighter and BAC felt that the P.45 offered great export potential.

Hawker Siddeley HS.1170B

This resembled the P.1154 and started life as the P.1163 with a single RB.163 and PCB. Developed into the HS.1170 by Kingston with a vectored thrust Bristol BS.94/5 and PCB, it was proposed in 1964 as a subsonic aircraft to a German nuclear strike fighter requirement called VAK.191, which was intended to replace the Fiat G.91. HS.1170 would be a joint programme with Focke-Wulf with the aircraft operating purely in the VTOL mode. It would have flown in 1966 and entered service in 1969 but it was never built and, instead, the German manufacturer produced and flew its FW 1262 design as the VAK.191B.

The HS.1170B was a larger strike/trainer version proposed to AST.362 in May 1964 by HSA (Folland) at Hamble. The fixed wing had 40° leading-edge sweepback, full-span slotted flaps and leading-edge slats for high lift and conventional ailerons. The all-moving tail had a similar planform to the wing and the usual P.1127-style bicycle undercarriage was employed with outriggers. A pitot type intake located either side of the fuselage just ahead of the wing was used since the aircraft's subsonic performance did not require anything more sophisticated. Fuel was accommodated in integral wing and fuselage tanks. HS.1170B's engine thrust was adequate for the AST's take-off requirement but its relatively low 'reheat' (PCB) temperature meant its supersonic performance was less than that of either P.45 variant.

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These projects were summarised by the Ministry's A T Jarrett and K W Clark on 24th September. Each project came in trainer and strike versions that shared identical airframes and engines, the only difference being the additional equipment and armament required for the strike role installed in place of the trainer's rear cockpit. The quoted data covers the strike variants, all of which had a 270nm (500km) radius of action; the trainers would each have been over 2,100lb (953kg) lighter. Jarrett and Clark noted that variable sweep granted the ability to vary the handling characteristics of the aircraft in step with a pupil's progress from the basic to the final operational trainer, so giving the ability to cover a wider range in the training programme than present advanced trainers. Each design had five weapon stations, four under the wings and one under the fuselage on the fixed-wing types, two under the moving wings and three under the fuselage for the VG P.45; sea level top speed for each design when carrying five stores was about Mach 0.7.

The authors concluded that, in terms of weight and general performance, there was little difference between these projects, so an AST.362 strike aircraft would weigh in at about 20,000lb (9,072kg), the advanced trainer at 18,000lb (8,165kg). The two roles seemed fairly compatible within one airframe. More specifically the VG P.45, at an extra cost of some 9%, offered advantages in performance and greater flexibility which should increase its export potential. The vectored thrust HS.1170B did not offer enough advantages in this context to offset its greater cost and the absence of engine-out safety. All the trainer versions could be in service in 1970, the VG striker in 1972 and the others in 1971.

Speaking recently to ex-Warton staff, there are strong opinions regarding variable sweep wings. Some felt that Barnes Wallis' Swallow concept was not good and essentially wasted effort. It could only have been made to work using fly-by-wire [FBW], a system first perfected over 20 years later. Many published works have criticised the abandonment of the Swallow, and the decision not to build the P.45, but the latter was too small for a VG wing, the penalties for using VG far outweighing its benefits. The main problem is the extra weight of a VG wing's pivot and actuating assemblies and the space that this mechanism absorbs, particularly if the pivot is housed in the fuselage.

The pivot itself is heavy while the wing needs a slot in the fuselage side into which it can fit when fully swept; this slot uses up valuable space. The result is that VG wings force a trade between weight and space against aerodynamic advantage – the benefits are that the same aircraft can fly at high supersonic speed (Mach 1.5+) and yet operate from short strips. As the sweep angle decreases it effectively thickens the wing and reduces the stalling speed so that the aircraft can take off and land at much slower airspeeds. There is no point in fitting VG for a Mach 1.1 maximum because this can be achieved in other ways; serious supersonic speed is the key. VG was fashionable in the 1960s but it only really proved practical and useful for an aircraft of Tornado size upwards (see Chapter 14). The AA-107 described shortly would have been too small for VG.

Hawker (Siddeley) HS.1173

Alongside the HS.1170B, Hamble also proposed its HS.1171 VG project to AST.362 which weighed about 20,000lb (9,072kg) and had two Rolls RB.172 engines. Another private proposal was Kingston's HS.1173. Kingston was very interested in the idea of a supersonic Hawker Hunter/de Havilland Vampire replacement which was affordable, flexible and quite the opposite of the P.1154. HS.1173 was a conventional Mach 2 design but it had no load-carrying structure below the cockpit floor. A large internal fuel volume was thought to be essential if the aircraft was to have a worthwhile supersonic endurance, and if the four underwing pylon stations were to be left free for ordnance. To this end the normal dorsal spine had been enlarged to form a tank running from cabin to fin which contained over half the internal fuel. Fuel was also housed around the intake ducts and the single-seater had an additional tank in the front fuselage which increased capacity from 580gal (2,637lit) to 700gal (3,183lit).

Double-slotted area-increasing flaps were provided together with a leading edge which drooped in two sections. Due to the large span of the trailing-edge flaps the ailerons were relatively small and at high speeds were augmented by spoilers. Rectangular two-shock intakes were chosen and the HS.1173 carried twin 30mm cannon beneath them solely for use in ground attack. Two ASMs or 1,000lb (454kg) bombs were carried on the inner underwing pylons and two 100gal (455lit) drop tanks on the outer pylons. As a single-seat strike aircraft, in 'clean' condition (internal fuel plus loaded cannon) it weighed 16,250lb (7,371kg); as an advanced trainer, 'clean' weight was 15,000lb (6,804kg). Range with external tanks and two 1,000lb bombs was 250nm (463km) at Mach 0.85. The study was terminated in March 1965.

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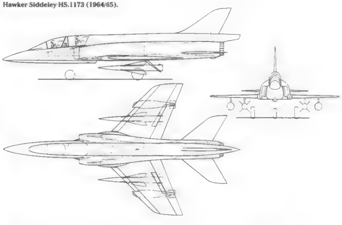
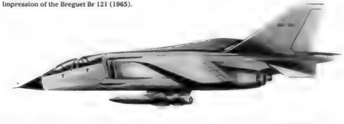
By September 1964 the British/French weight discrepancy had narrowed and on 5th November Naval and Air Staff Requirement (NASR) 362 for an advanced trainer was

Hawker Siddeley HS.1173 (1964/65).



Impression of the Breguet Br 121 (1965).



XW563 in May 1971 after receiving a new nose with a computer-controlled navigation and weapons aiming sub-system (NAVWASS). A similar nose became common to all Jaguar GR Mk.1 aircraft.

endorsed by the British Operational Requirements Committee as the basis for a joint study. High-level staff discussions with the French resumed on 5th February 1965 and late in the month agreement was reached for HMG and the French Government to co-operate in developing a fixed-wing supersonic strike trainer and to collaborate on other VG studies. On 26th March it was confirmed that an advanced training aircraft that would meet both countries' needs could not economically be developed from a VG operational aircraft. Separate discussions on VG aircraft now followed which were to crystallise into the Anglo-French Variable Geometry Aircraft described in Chapter 14; VG for the trainer was dead.

France's original requirement had been for an essentially simple aircraft called ECAT (*Ecole et d'Appui Tactique*) and the Breguet Br 121, owing much to the earlier Br 1001 Taon fighter, was favoured in a competition which included the Potez P.92 and Dassault Cavalier. The Protocol covering Anglo-French co-operation on the strike/trainer (and other projects) was agreed on 17th May 1965 when it was announced that an MoU had been signed between Britain and France for the mutual development of a trainer and ground attack aircraft; BAC and Rolls-Royce were nominated as the British contractors.

Nine days later a combined MoD/MoA/BAC team visited Villacoublay for a presentation on Breguet's Br 121. The project was to be evaluated to see if it could meet the joint requirement and in mid-September cockpit mock-ups of the 121's basic design and an improved droop nose version were examined at Warton by RAF/RN specialists and French representatives. A nose with a downward view of 8.5° was accepted by both parties and discussions looked at alternative engines before the company's proposals and provisional specification was completed on 3rd December. A wing thickness redesign was needed to ensure a high-altitude supersonic performance of Mach 1.3 in a 1.5g turn and this was agreed in January 1966. (Essentially BAC's part in the programme was to design and fit a supersonic wing to the Br 121.)

During January there were indications that a British tactical version might now also be required. The prototype specification was finalised in March and the requirement for a British tactical version was endorsed on 19th May. By now the Royal Navy had withdrawn so the requirement became Air Staff Requirement ASR.362 with the 'N' omitted. The aircraft was named Jaguar in June 1966 and was to be built by SEPECAT (Société Européenne de Production de l'Avion ECAT). During August good progress was made in harmonising the layouts of all the versions and the specification for the British S attack prototype was agreed in February 1967.

The second British Jaguar S strike prototype XW563, seen here in 1970, was detailed to clear the type's nav-attack system.

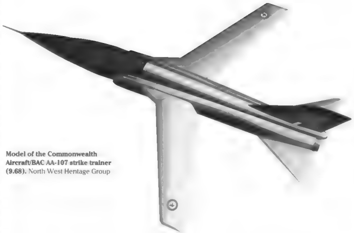
The versions ordered were the French Jaguar E trainer which became the first prototype to fly on 8th September 1968, the French tactical support Jaguar A flown on 23rd March 1969, the British tactical support Jaguar S which first flew on 12th October 1969 and became the GR Mk.1 in RAF service, and the British Jaguar B trainer (T Mk.2) flown on 30th August 1971. Their differences were mainly in equipment but a variant for the French Navy called Jaguar M was abandoned in 1973 having flown in 1969. The engine used in these aircraft was the Rolls-Royce/Turboméca Adour, first run on 10th May 1967 and based on and developed from the RB.172.

On 19th May 1970 VCAS noted that the RAF's requirement for Jaguar S was currently 86 aircraft, to replace 70 McDonnell Douglas Phantom FGR Mk.2s in the ground attack and recce roles in 1974/5. The total buy of trainers was put at 130. The Air Staff had long been aware that the number of aircraft available for close support was inadequate and well below that necessary to meet the task. Recent changes to NATO strategy had accentuated this shortage (this was the switch to Flexible Response which required NATO forces to continue to maintain a deterrent posture and yet, at the same time, put more emphasis on conventional forces to avoid early recourse to nuclear weapons). At the same time it had become increasingly evident that introducing Jaguar to the Advanced Flying School would very substantially increase the costs of flying training. Clearly the proportion of single-seat operational to two-seat trainer had to be altered and a less sophisticated and much cheaper aircraft be provided for advanced training.

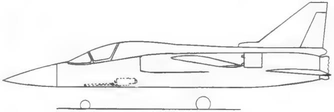
As a result the RAF eventually received 165 GR Mk.1s and 35 two-seat conversion aircraft, with deliveries beginning in 1973, and the original need for advanced trainers was met by the HS.1182 Hawk. So by a roundabout method, starting with a trainer requirement, the RAF acquired an outstanding attack machine which has served well, and still serves today. Another 200 were bought by France, many more Jaguar Internationals built by BAC were sold overseas and a licence build was established in India where some production continues to this day.

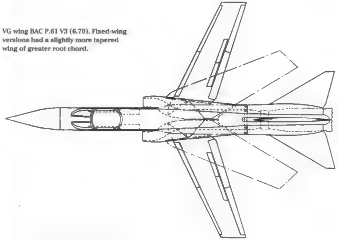
BAC P.60, P.61 and AA-107

In September 1968 a collaborative supersonic VG strike trainer design study was undertaken by Commonwealth Aircraft of Australia and BAC Warton called the (Anglo-Australian) AA-107. This advanced trainer with an appreciable close support capability was to be powered by one reheated Adour engine



Model of the Commonwealth Aircraft/BAC AA-107 strike trainer (9.68). North West Heritage Group





VG wing BAC P.61 V3 (6.70). Fixed-wing versions had a slightly more tapered wing of greater root chord.

and have a moderate supersonic performance of the order of Mach 1.45. There was some interest but the RAAF reached the same conclusion as the RAF in that its specialised training aircraft did not need supersonic capability. With no overseas orders the project died in 1970 but from it BAC acquired background knowledge on the development of, and markets for, a small relatively simple sub-Jaguar type of aircraft with two seats, adequate avionics for close support, a reheated engine and a reasonable payload.

At the same time, BAC was heavily involved in RAF trainer studies and this eventually yielded a family of designs (i.e. having a definite geometric resemblance with one another) that closely resembled and owed much to the AA-107, which itself became part of the total family. This embraced the P.60 series of trainer-type aeroplanes powered by a single Adour and the more combat-capable P.61 series powered by an 'advanced engine' (soon clarified as the MRCA's RB.199) which needed a larger duct and reheat pipe and a deeper fuselage to accommodate the increased mass flow. The range encompassed trainers through close support to machines with a performance sufficient to be classified as air superiority and interceptor. Panavia, the joint company responsible for the MRCA Tornado, was responsible for the P.61 which was called the PANNAP (Panavia New Aircraft Project) family. In some respects this was a minor study to keep Panavia's design staff busy.

The family divided into two branches, one with a thin fixed 35° sweep wing, the other pivoted at the fuselage side for VG between 27° and 69°; the latter also needed a large slot in the fuselage which had to be sealed at all conditions of wing sweep. Both groups shared a very similar fuselage, full-span flaps and slats on the wing, spoilers and an all-moving differential tail, although the fixed wing offered a simpler proposition. External stores were mounted tangentially under the fuselage and on wing pylons and fuel was carried in the centre fuselage and, in some cases, in the wing. Switching from the Adour to a RB.199 would add structural and mechanical complication so the fixed wing was intended to retain around the same level of airfield, range and supersonic performance but, to compensate, it removed the complexity of the VG wing. By June 1970 the two groups comprised the following, all of which looked similar except for the wing.

P.60 F1 – A basic advanced trainer powered by an unreheated Adour.

P.60 F2 – A close support aircraft with advanced applied trainer capability powered by a reheated Adour. One DEFA cannon was mounted under the second cockpit, external stores could be carried on wing pylons (two per wing) and four hardpoints under the fuselage (two rows of two) and another centre fuselage store point would normally be used for an external tank. Internal fuel in wing and fuselage tanks totalled 3,200lb (1,452kg).

P.61 F1 – Advanced applied trainer with close support capability powered by one unreheated RB.199. The DEFA cannon and stores arrangement were identical to P.60 F2 but the weapon pylons would not be used in the trainer role. Internal fuel 3,750lb (1,701kg).

P.61 F2 – Close support aircraft near identical to P.61 F1 but with a reheated RB 199.

P.61 F3 – Interceptor close support air superiority aircraft identical in layout to P.61 F2 but with the rear cockpit replaced by avionics and gun ammunition, leaving the nose free for a search radar. Two DEFA cannon were mounted under the 'rear' cockpit position. At a take-off weight of 15,000lb (6,804kg), both P.61 F2 and P.61 F3 could reach 30,000ft (9,144m) in 1.4 mins and had a low-level and high-level range of 690nm (1,278km) and 1,500nm (2,778km) respectively. Their ceiling was 57,000ft (17,374m).

P.60 V1 – A basic advanced trainer powered by an unreheated Adour with the VG wing modified over the inboard section to convert it to a fixed wing.

P.60 V2 – Advanced applied trainer with close support facility, reheated Adour and wing and centre fuselage identical with P.60 V1. Armament as per P.60 F2, internal fuel 3,588lb (1,628kg).

P.60 V3 – The aircraft was previously the AA-107 and was identical to P.60 V2 except that the wing was now VG pivoted, which meant that the wing pylons must now swivel. Internal fuel 3,500lb (1,588kg).

P.61 V1 – This was the VG version of the P.61 F1 trainer, internal fuel 3,500lb (1,588kg).

P.61 V2 – Close support aircraft near identical to P.61 V1 but with a reheated RB.199.

P.61 V3 – Interceptor close support/air superiority aircraft identical in layout to P.61 V2 and which was the VG version of the P.61 F3.

These designs essentially formed a study to see what could be done within the concept of an aircraft family but they also provided a useful comparison to the MRCA (see Chapter 14). The fixed-wing P.61 F3 with a single RB.199 weighed in at 15,109lb (6,853kg) when MRCA was estimated to be 35,277lb (16,002kg) and its simple pitot intake still allowed a maximum Mach 1.85 and a ceiling of 57,000ft (17,374m). There was probably little likelihood that a P.60/P.61 type aircraft would ever have been built.

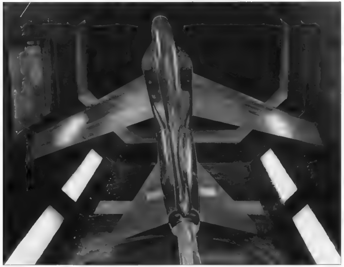


Photo dated 4.2.71 showing a wind tunnel model of a fixed-wing member of the PANNAP P.61 family.
BAE Systems

Strike/Trainers – Estimated Data

Project	Span ft in (m)	Length ft in (m)	Wing Area ft² (m²)	t/c %	All-Up-Weight lb (kg)	Powerplant Thrust lb (kN)	Max Speed / Height mph (km/h) / ft (m)	Weapon Load lb (kg)
Folland Fo.147	36 6 (11 1) forward, 18 0 (5.5) swept	51 0 (15 5)	186 (17 3) forward, 195 (18 1) swept	not given	18,500 (8,392)	2 x RB 153 reheated	Mach 2 2 initially	None
Folland Fo.148	35 0 (10.7) forward	47 0 (14.3)	?	?	16,500 (7,484) armed version	1 x RB 153-61 6,720 (29 9), 11,750 (52 2) reheat	Mach 2 05	2,000 (907) of stores including 2 x Bullpup ASMs or Red Top AAMs
BAC Type 593 Aircraft A	33 5 (10.2) for'd, 22 2 (6.8) swept	37 8 (11 5)	160 (14 9) (not inc fixed forewing)	10	11,140 (5,053)	2 x J85-GE-13 8,140 (36 2) reheat	Mach 1 6	None
BAC Type 593 Aircraft B	35 7 (10.9) for'd, 23 7 (7.2) swept	40 4 (12.3)	180 (16.7) (not inc fixed forewing)	10	12,490 (5,665)	1 x RB 153-61 11,750 (52.2) reheat	Mach 1.75	None
BAC **P.45** (VG)	35 0 (10.7) forward, 21 0 (6.4) swept	50 0 (15.2)	200 (19 6) forward, 240 (22 3) swept	12 forward, 5 75 swept	20,500 (9,299)	2 x RB 172-49R 7,710 (34.3), 13,050 (58.0) reheat	Mach 1.1 at sea level, Mach 2.2 at 36,000 (10,973)	ASMs and bombs
BAC **P.45** (fixed wing)	25 0 (7 6)	50 0 (15.2)	300 (27.9)	4	20,000 (9,072)	2 x RB.172-49R 7,710 (34.3), 13,050 (58.0) reheat	Mach 1.1 at sea level, Mach 2.2 at 36,000 (10,973)	ASMs and bombs
HSA **HS.1170B**	25 0 (7.6)	50 0 (15.2)	200 (18 6)	6	20,850 (9,458)	1 x BS.94 5 13,500 (60.0), 19,000 (84.4) PCB	Mach 1.1 at sea level, Mach 1 7 at 36,000 (10,973)	ASMs and bombs
HSA **HS.1173**	25 0 (7.6)	45 0 (13.5)	210 (19.5)	6 root 4 tip	20,250 (9,185)	1 x RB.172-57AR 13,000 (57.8) reheat	Mach 1 4 at sea level, Mach 2 4 at 36,000 (10,973)	2 x 30mm cannon; 2 x 1,000 (454) bombs or 2 x ASM
SEPECAT Jaguar GR Mk.1	28 6 (8.7)	55 2½ (16.8) with probe	260.3 (24.2)	?	c34,000 (15,422)	2 x Adour 102 5,115 (22 7), 7,305 (32 5) reheat	Mach 1 1 839 (1,351) at sea level, Mach 1 6 1,056 (1,699) at 36,000 (10,973)	2 x 30mm Aden cannon, 2 x AAMs, 10,000 (4,536) of stores including bombs, ASMs & RPs
BAC **P.61 F3**	26 10 (8.2)	40 0 (12.2)	160 (14.9)	5	15,109 (6,853), 17,745 (8,049) with Taildog missiles	1 x RB 199 8,394 (37 3), 14,997 (66 6) reheat	Clean Mach 1.85 at 36,000 (10,973), with 6 AAM, Mach 1.64 at 36,000 (10,973)	2 x 30mm DEFA cannon, 8 pylons for bombs, RPs, ASMs, AAMs
BAC **P.61 V3**	28 0 (8.5) forward, 16 6 (5.0) swept	40 0 (12.2)	not given	10	15,428 (6,998)	1 x RB.199 8,394 (37.3), 14,997 (66.6) reheat	Clean, 69° sweep: Mach 1.95 at 36,000 (10,973)	2 x 30mm DEFA cannon, 8 pylons for bombs, RPs, ASMs, AAMs

Chapter Fourteen

A Destructive Localised Storm

A Tornado GR Mk.1 of 27 Squadron seen in the Far East during 1990. BAe Warton

Background to Tornado: 1964 to 1982

The intention was to replace the TSR.2 with two strike aircraft types, the F-111K and a collaborative project to go with it called the Anglo-French Variable Geometry Aircraft or AFVG. The latter aeroplane would also help Great Britain to retain its capability to develop advanced combat aircraft and, like the Jaguar, it was to be an Anglo-French product, although BAC would design it together with Dassault rather than Breguet. Eventually this too was cancelled and replaced by a programme that was to give the RAF the Tornado, a bomber which since 1990 has been to war on several occasions.

Anglo-French Variable Geometry Aircraft (AFVG)

Parametric studies made during 1964/65 for an interceptor with strike capability concluded that a requirement could be met by a VG aircraft weighing about 40,000lb (18,144kg). The Anglo-French discussions of February to April 1965 (see Chapter 13) also embraced possible VG projects and when the MoU was signed on 17th May it included a decision to collaborate on a VG aircraft. The UK Air Staff's main interest was for an interceptor to replace the Lightning but the RAF, Royal Navy, French Air Force and French Navy were all interested in this AFVG project, the French specifically for intercept and strike. It would use SNECMA/Bristol Siddeley M.45G bypass engines and specification 260 and ASR.388 were issued on 13th July to define the British version. They requested a 2,500lb (1,134kg) weapon load, a maximum 920mph (1,480 km/h) at sea level and Mach 2.5 at altitude, a sustained ceiling of 60,000ft (18,288m), 400nm (741km) radius of action in the strike recce role, ferry range of 3,500nm (6,482km) and a three-hour Combat Air Patrol.

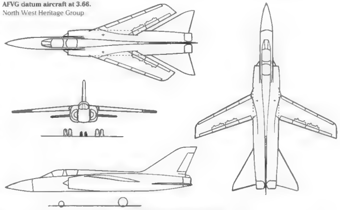
A feasibility study began on 1st August and quickly revealed some disappointing features for the M.45G which meant critical aspects of performance had to be based on a smaller, hypothetical engine. Designs were studied at 30,000lb, 40,000lb and 50,000lb (13,608kg, 18,144kg and 22,680kg) all-up-weight and at 16,000lb (7,258kg) for the French Navy's carriers. From November much of the work centred on securing a better engine/airframe match within the French aircraft carrier limits while, as an outcome of the February 1966 Defence Review which ended Britain's new large carrier programme, RN interest in AFVG ceased. Now the British AFVG would be an aircraft optimised for conventional strike/recce operations to complement the F-111K when the V-bombers were phased out from 1975; any resultant interceptor capability was considered incidental and secondary.

In March the RB.153 was proposed as an alternative to M.45G and in May Ministers noted that both countries needed the aircraft by 1974, although the timescale for beginning the prototype had slipped. At this time the datum aircraft had semi-circular intakes with conical centre-bodies, full-span leading-edge slats and double-slotted extending trailing-edge flaps, spoilers for low-speed flight and all-moving tailerons (where both sides of the tail were used as primary control surfaces in both pitch and roll). The wings pivoted on bearings inside the fuselage and carried 330gal (1,500lit) of internal fuel; another 990gal (4,501lit) was housed in the fuselage and 55gal (250lit) in the fin. One French 2,500lb (1,134kg) 'special (nuclear) weapon' could be carried below and partly within the fuselage and there were three underfuselage air-to-air missile stations semi-recessed to reduce drag. The datum AFVG could take four 1,000lb (454kg) bombs under the fuselage and still retain its supersonic performance but larger loads under both fuselage and wings (up to 18 1,000lb bombs) kept it subsonic; in this full load condition its wings stayed in the forward position. Two 30mm cannon could be loaded into the fuselage, aft of the intake, by removing the auxiliary fuel tanks.

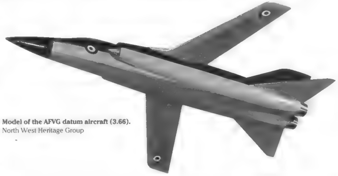
For the strike role a forward-looking radar with an 80cm to 90cm dish would undertake terrain following, ground mapping and radar ranging and an inertial platform, possibly Doppler monitored, would also be carried. Design dive speed with wings swept was 920mph (1,480km/h) (Mach 2.3 for short periods), with wings unswept 518mph (834km/h) Mach 0.8. Time to climb to Mach 2.2 at 50,000ft (15,240m) with 1,500lb (680kg) of missiles was 4.95 minutes (requirement 5 minutes), acceleration from Mach 0.7 to 2.2 at 11,000m was 2.25 minutes, ferry range was 3,780nm (7,000km), land-based strike range (four 1,000lb bombs released) was 785nm (1,454km), 1,220nm (2,260km) with wing tanks, and supersonic radius of action was 360nm (667km). The first prototype flight was intended to be in the first half of 1968 and a detailed AFVG mock-up was built at Warton.

Thanks to the apparent cost of the datum AFVG, studies were requested in July 1966 for alternatives, but a smaller design demonstrated that a significant reduction in unit cost could only be achieved by an aircraft with insufficient performance to meet the ASR while a single-engine type offered only a small cost saving. Neither was acceptable and it was agreed by Anglo-French Ministers on 7th November that only the datum aircraft merited further study. In September it had been recommended that, should France withdraw, a UK variable geometry aircraft should continue as a fallback. The French still had to decide on their budget before AFVG's future could be clarified but they rejected the RB.153, insisting on the performance being met by one of the M.45 family. However, the M.45G9 (an RB.172 derivative) showed an imbalance between the strike and air defence roles so a further type, the M.45G10, was proposed by the engine manufacturers.

A revised timetable – airframe Project Study to start 1st April 1967, completed 30th September and evaluated by end December so that the Prototype Stage could begin on 1st January 1968 – was accepted by Ministers on 16th January 1967. Aircraft with alternative versions of the M.45 were now examined but by March 1967 the latest estimates indicated that an initial in-service date, with limited CA Release, could not be expected before January 1975. On 8th May the French Air Staff target was confirmed which requested a maximum speed at altitude of Mach 2.2 and low-level strike radius of 700km (435 miles) on internal fuel. Both countries agreed to go



AFVG datum aircraft at 3.66.
North West Heritage Group



Model of the AFVG datum aircraft (3.66).
North West Heritage Group

ahead with a Project Study to meet these limits; BAC would lead on the airframe, SNECMA on the engine, but a 50/50 principle was to be maintained. The M.45G10 engine was now accepted by both countries.

However, when the Conseil de Defense met on 15th and 16th June, the French Government's ratification of the Ministers' agreement of 8th May was not given and further progress now depended on the political outcome (as a consequence the UK's fallback position was re-examined). On 29th June 1967 the French withdrew from the joint AFVG project for 'financial' reasons, French Defence Minister Pierre Messmer notifying UK Defence Secretary Denis Healey of the decision even though both countries had at last successfully reconciled their differing operational requirements into the one aircraft. In truth, France had generally been very lukewarm towards the AFVG while Dassault was hostile and even developed an indigenous VG aircraft called the Mirage G. No secret was made of the G's existence which clearly conflicted with AFVG and threatened the programme. The British AFVG requirement had primarily been 'East of Suez'. (Some in industry said that Healey had been mesmerised by Messmer throughout the whole affair.)

United Kingdom
Variable Geometry Project (UKVG)

The UK did continue its VG work and during July 1967 a Ministry of Technology (MinTech) Project Study was proposed to look into the cost and feasibility of a UKVG, similar in strike performance to the AFVG, and collaboration with other countries. BAC Warton was asked to undertake a four month Project Definition to ASR 388 beginning on 1st August. Parameters were low-level dash at Mach 0.9, at high altitude with reheat Mach 2 to 2.2, ferry range 2,800nm (5,186km), high-level range (low-level over the target) with external fuel and four 1,000lb (454kg) bombs up to 1,000nm (1,852km), and low-level range (internal fuel only and four 1,000lb bombs) up to 400nm (741km).

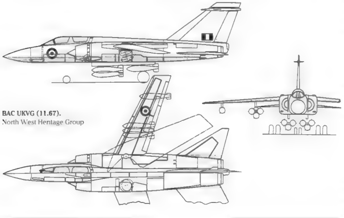
Also in July McDonnell Douglas in America began studies for a swing-wing Phantom called the F-4M(VFS) as a possible AFVG replacement. This could reach Mach 1.05 in a low-level dash and Mach 2.41 at height and was powered by two RB.168-27R Speys. It had a wing area of 420ft² (39.1m²), take-off weight of 53,420lb (24,231kg) and a supersonic combat ceiling of 57,600ft (17,556m), but the US Department of Defense could not envisage offering any assistance to the project and it was quickly dropped.

An early BAC drawing, dated 5th September 1967 and called P.51, showed an aircraft with two RB.153-67-02 bypass engines. A UKVG brochure for a near-identical aircraft was completed in November 1967 with figures based on the RB.153-02, but an alternative was the BS.143, a new unit of 8,122lb (36.1kN) dry thrust and 13,998lb (62.2kN) reheated which used a scaled RB.193 IP compressor and fan and the M.45H HP spool (no decision was to be made on the UKVG's engine). BAC noted that, despite variations in requirements during the period, the VG aircraft's basic layout had remained substantially the same for over three years. Consequently BAC had great confidence in the design which was backed up by over a million wind tunnel data and pressure points plus engineering rig tests on the wing hinge and its associated structure. The design work needed to find a suitable VG pivot bearing with a sufficient fatigue life had developed into a major research programme.

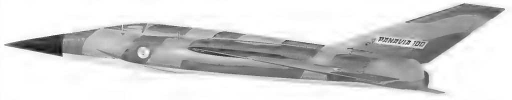
UKVG had low-mounted all-moving tailerons (which permitted the use of full-span wing trailing-edge flaps), and the wings again pivoted just inside the fuselage contours; this pivot position eliminated the need for leading-edge gloves which improved the take-off and landing characteristics. It was found fairly early in the feasibility phase that overall cost-effectiveness was best secured by fitting full-span leading-edge and trailing-edge high-lift devices on the wing for take-off and landing. Having no leading-edge glove meant full-span leading-edge slats were possible and beneficial in contributing to the maximum lift coefficient. It was also proposed to use these devices, partly extended, to enhance subsonic manoeuvrability.

The aircraft had translating conical centre-body intakes situated well forward of the wing (box intakes would have been simpler and easier but slightly heavier and not so effective). Their location, compared to an underwing intake, greatly reduced boundary layer bleed and diverter problems and gave a long settling length between the intake throat and the engine face to help damp out any fluctuations in airflow, an important feature for bypass engines which were more sensitive to flow fluctuations than a straight turbojet. All stores were mounted on external pylons beneath the fuselage and wings. Eight attachment points were available under the fuselage for pylons and a ventral fuel tank and two more were on each wing. The inboard wing store locations were capable of swivelling which allowed the wing to be swept when carrying stores. Two cannon were carried internally but this armament was not specified in the definitive mission performance estimations.

The tailerons were the primary source of roll control when the wings were fully swept and they were set well below the wing plane since this was found aerodynamically to be the best practicable position. When the wings were in their forward position, primary roll control came from spoilers on the wing, though there was still a limited amount from the tailerons. Most of the structure was semi-monocoque with the use of machined frames and forgings kept to a minimum. Aluminium-copper alloys were used for most of the airframe to give good fatigue, stress corrosion and high-temperature properties. Steel was only used in regions of high stress



BAC UKVG (11.67).
North West Heritage Group



such as the wing root diffusion member, lugs of the wing centre section and tailplane spigots. Titanium was restricted to firewalls and frames around the brake parachute and flap supports. The avionics were housed immediately behind the nose radar scanner and beneath the pilot's floor. Design dive speed was 920mph (1,480km/h), unswept Mach number limit about 0.8, 1g ceiling about Mach 1.1 to 1.8 at 58,000ft (17,678m) and UKVG could reach about Mach 1.47 at 78,000ft (23,774m) in a zoom climb.

On 25th October 1967 BAC presented a UKVG variant to West German representatives in Bonn, which was designed to meet their requirements for a Heavy Airborne Weapon System; the response was disappointing. Possible collaboration was again explored but West Germany's in-house NKF studies (a VG project of its own replacing the defunct German/American AVS V/STOL strike fighter project) ensured that little interest was received for a UKVG type. In early December MinTech asked BAC to investigate a fighter application and the use of advanced technology in engine and airframe because, although the RAF still wanted a strike/recce aircraft, an air defence type would be needed later on.

BAC Advanced Combat Aircraft

Advanced Combat Aircraft studies continued through the first half of 1968, primarily against the all-weather low-level strike and reconnaissance role but including single-engine and single-crew variants. The Advanced Combat Aircraft concept, with a set of missions of generally shorter range, replaced UKVG although steps continued towards possible collaboration with Canada and the F-104 Consortium. The latter, comprising Germany, Italy, Belgium and the Netherlands in a single group, had been set up to replace their Lockheed F-104 Starfighters with a common aircraft.

After a meeting on 16th and 17th May in Rome between the Chiefs of Staff of the F-104 Consortium countries, Britain was invited to join a Working Group intending to finalise an operational requirement by December 1968. In July 1968 ASR.388 was superseded by AST.392 for an Advanced Combat Aircraft and an MoU was signed by Britain, Canada and the F-104 Consortium to define an aircraft to meet the needs of the member countries. It was to be called the Multi-Role Combat Aircraft or MRCA and was to be in service by 1975. (Back in January the F-111K's cancellation had brought the end of the old 'OR.339/TSR.2 task'.) The RAF MRCA's first-priority targets would be East German airfields from which enemy close support might be operating; interdiction and targets deeper in Warsaw Pact territory would be less important.

Panavia MRCA (Tornado)

By November 1968 studies had advanced sufficiently to suggest there was a good chance of meeting the requirements of Germany, Italy, the Netherlands and the UK (Belgium and Canada had by then dropped out and the Netherlands followed in July 1969). Using parameters agreed by the Chiefs of Air Staff on 17th December, a Feasibility Study for MRCA was conducted by a joint company, Panavia Aircraft GmbH, which was presented on 31st January 1969. Officially registered in Germany on 26th March 1969 and formally established in September, Panavia was formed by BAC, Messerschmitt-Bolkow-Blohm [MBB], Fiat and Fokker and based in Munich. BAC and MBB were still working separately on different layouts but were exchanging views.

The Feasibility Study reported that a viable collaborative project was possible based on a twin-engine VG design having good manoeuvrability and the capacity to operate from short airstrips. Handel Davis of the Steering Committee noted that there were 'grounds for being more hopeful about the outcome of

Above: **The first MRCA model to be shown to the public but, when it appeared at the Paris show in 1969, the quite different final configuration had already been agreed for some time. This has blended intakes, an undersize canopy and pivots well inboard when MRCA's were further out.** North West Heritage Group

Right **A Mk.1 Tornado from 617 Squadron painted in desert camouflage. It carries two ALARMs under the fuselage, two underwing tanks, a BOZ chaff dispenser beneath the starboard wing and a Sky Shadow ECM pod under the port wing.** BAe Warton

A Tornado GR Mk.1B of 617 Squadron carrying Sea Eagle ASMs on underfuselage stations. BAe Warton

the exercise than we have been at any time in the past'. A number of important compromises had to be made to reconcile differing national requirements; in particular the RAF had to accept a reduction in range below what it would have preferred. A decision on the engine had still to be made but the Feasibility Study was conducted using the characteristics of the RB.199.

Panavia's baseline aircraft was presented on 14th March 1969 with the RB.199-33R but this was quickly overtaken by a modified design incorporating an advanced technology three-shaft engine with a higher thrust/weight ratio which was based on early RB.199-34R data. This offered a substantial performance improvement and reduced aircraft size but Germany insisted on a competition between engines from Rolls-Royce and Pratt and Whitney. This became one of the few sticking points since Germany wished to press ahead using the P&W JTF-16 (TF-30) but information on it was denied to the Netherlands and Italy.

At this stage Germany and Italy required a single-seater for close air support and as an air superiority fighter respectively; the RAF needed a two-seater for strike and reconnaissance but with the potential for fighter development later. According to the Air Staff, Britain's MRCA would fill three major roles:

i. Strike and Reconnaissance. Following the collapse of successive plans to replace the Canberra, measures taken to provide a stop-gap and meet, in part, Britain's NATO obligations included prolonging the Vulcan's life, using Buccaneer Mk.2s in the overland strike role and extending the operational life of the Canberra PR Mk.9 to compensate for the inadequacies of the Buccaneer Mk.2 in the recce role. The relatively slow Vulcan was expected to become increasingly vulnerable to Warsaw Pact defences, the Buccaneer lacked terrain-following radar and a blind nav/attack capability and so would also become increasingly vulnerable during the late 1970s, and Canberra was an old design restricted by limited performance. Each needed replacing and initial CA Release to the Service was required by first quarter 1976.
ii. Air Defence. A new aircraft would be needed to replace the Phantom from 1979.
iii. Maritime Strike. A replacement for the Buccaneer Mk.2 would be needed for maritime operations from about 1982.

In May 1969 Britain agreed to participate in the Project Definition Phase, which was concluded in spring 1970. Shortly before it was complete the Germans, having long campaigned for the single-seat Panavia 100, announced their decision not to proceed with it but to adopt the twin-seat Panavia 200 which was virtually identical to the RAF aircraft. This would cut development costs but it was a blow to the Italians, who could not continue with the single-seat MRCA in isolation and there was some concern that they might drop out. As a minority partner Italy was extremely vulnerable to any changes made by the two majority partners. At this point Germany stated a requirement for 600 aircraft (later cut to 420), Italy 200 and the UK 385. The Air Staff noted that MRCA was 'an advanced aircraft but less ambitious, in relation to the current state of the art, than TSR.2'.

In June 1969 a tri-national company called Turbo Union Ltd, embracing Rolls-Royce, MTU and Fiat, was set up at Bristol to produce the MRCA's supersonic lightweight RB.199-34R reheated bypass turbofan. The decision to use this 'paper' engine instead of the American JTF-16 was not announced until September but, eventually, the RB.199 was to become the largest single-engine production project carried out in Europe. It was a three-shaft augmented turbofan of extremely advanced design which used modular construction to assist rapid stripping and rebuilding, and it was first bench tested on 29th September 1971. A detailed airframe workshare was finalised in February 1970, Britain being allocated the nose and tail, Germany the centre fuselage and Italy the wings, and the development phase, essentially the go-ahead for MRCA, began on 22nd July.

The first prototype flew on 14th August 1974 when it became the first British-participation VG aircraft to fly; MRCA was named Tornado that September, rather than Panther as suggested by Panavia. A total of 992 aircraft were eventually built for the three participating countries and for Saudi Arabia. The RAF received 228 interdictor/strike (IDS) aircraft (allocated Warton project number P.67 in 1971), most of which were GR Mk.1s covered by ASR.392; the type entered RAF service in 1982. ASR.395 described the Tornado F Mk.2 and Mk.3 air defence fighter variants (ADV – Warton P.68) designed at British expense for the RAF, the first flying in October 1979. This was a modified IDS with a longer fuselage and, politically, was the right direction to take because it could be done as a UK-only aircraft since the parts affected were all made in the UK; altering German-made parts would have been a more sensitive and difficult option. A mid-life update under SR(A).417 is intended to see 142 GR Mk.1s upgraded to GR Mk.4 standard with more advanced weapons and equipment. The first Tornado GR Mk.4 flew on 29th May 1993.

In the 1970s it became declared UK policy that major new national defence projects could not be funded alone and it was the MRCA Tornado which set the pattern for collaboration. Generally the programme ran very smoothly and it was never acrimonious. When Tornado IDS arrived in Germany it gave the RAF a true low-level day/night and all-weather aircraft and enabled the Service to make a major contribution to NATO. Since then it has racked up an impressive record of action and service and in the 1991 Gulf campaign performed outstandingly. It proved to be the right aircraft to develop at the time yet the flight envelope is similar to TSR.2 cancelled so long before.

Because Tornado is so complex there was little chance that it could have been produced as a single-seater in the way Germany and Italy had wished; those countries judged their needs on F-104 experience. Today Eurofighter Typhoon has a much-simplified cockpit and the pilot's workload is reduced, so it should be possible now to design a large single-seat strike aircraft. Tornado was something of an old-fashioned design in that it lacked fly-by-wire and other advanced electronics; the time delay needed to mature such new technologies would have delayed the aircraft's entry into service, so they were not employed.

Tornado benefits fully from its swing wings. To make the pilot's ride comfortable during high-speed flight at low level in turbulent conditions the wing loading needed to be high. A small highly swept wing is a great help in reducing gust effects and when a VG wing is swept back the increase in lift from gusts (i.e. bumps) is much less, which gives an increased fatigue life. However, Tornado also needed to get out of short airfields with runways around 3,000ft (914m) long but it could not do this with a normal swept wing. The VG wing in its forward position does the job and this capability was fundamental in achieving Tornado's major goals; in fact it made VG practical and almost necessary for a strike aircraft.

Matching the development of complex low-level strike aircraft like TSR.2 and Tornado came developments in weaponry and systems. Terrain-following radar was vital for low-level flight in all weathers while the introduction of laser-guided bombs and advanced ASMs allowed aircraft to hit targets far more accurately. The BAe ALARM air-launched anti-radiation missile to AST.1228 was one of a new breed of ASMs designed to lock on to the emissions from enemy ground radars and then destroy them. Tornado can apparently carry more than 70 different kinds of store, all externally except for its guns (there is no internal bay) including the now withdrawn WE.177B freefall nuclear bomb. One piece of ordnance specifically designed for Tornado was the Hunting JP.233 airfield denial weapon which dispensed 60 runway cratering munitions plus additional area-denial mines that were intended to hamper follow-up repair operations. Each Tornado GR Mk.1 could take two JP.233s but the GR Mk.4 does not carry it or any nuclear weapons. Tornado GR Mk 4's are not intended to overfly their targets but instead will use stand-off weapons as their primary store.

The last of the RAF's nuclear weapons, the WE.177, was withdrawn at the end of March 1998, a move that signified the end of the Service's nuclear strike role after more than 40 years. The responsibility for providing Great Britain's nuclear deterrent now rests with the Royal Navy and its submarine-launched Trident missiles.

ASR.388 Multi-Role Projects – Estimated Data

Project	Span ft in (m)	Length ft in (m)	Wing Area ft² (m²)	t/c %	All-Up-Weight lb (kg)	Powerplant Thrust lb (kN)	Max Speed / Height mph (km/h) / ft (m)	Weapon Load lb (kg)
AFVG (Datum 3/66)	42 8 (13.0) forward, 23 3 (7 1) swept	53 10 (16 4)	198 (18 4) forward (nett), 169 6 (15 8) swept (nett)	12 forward, 5 7 swept	38,107 (17,285)	2 x assumed 6,940 (30.8) 12,120 (53 9) reheat	Mach 2 2 at height	2 x 30mm cannon, 3 x AAMs, 1 x nuclear weapon, 18 x 1,000 (454), or 2 (4?) x Martel
UKVG	45 10 (14.0) forward, 27 0 (8 2) swept	57 5 (17 5)	300 (27.9) forward, 374 (34 8) swept	12 forward, 5 7 swept	58,344 (26,465) (18 x 1,000lb), 45,937 (20,837) (4 Martel)	2 x RB153-02 7,674 (34 1), 12,972 (57 7) reheat	Mach 2 3 between 36,000 (10,973) and 45,000 (13,716)	2 x 30mm cannon, 18 x 1,000 (454) bombs or 4 x Martel ASMs under wing fuselage
Panavia Tornado (IDS - flown)	45 7 (13 9) forward, 28 2 (8 6) swept	54 10 (16 7)	286 3 (26 6) (25° sweep)	?	61,620 (27,951)	2 x RB 199 Mk 103 9,100 (40 4), 16 075 (71 4) reheat	Over 920 (1,480) at low level, Mach 2 2 at height	2 x 27mm cannon, more than 19,840 (9 000) of external stores

Chapter Fifteen

AST.396

Impression of the P.153 small combat aircraft.
BAe Brough Heritage Centre

A Battlefield Aircraft: 1970 to 1975

In 1970 the Air Staff was expecting the RAF combat force's close support/short-range reconnaissance component to be composed exclusively of Harriers and Jaguars. The former was scheduled to be withdrawn from service during 1980 and the Jaguar in 1984, so a replacement would be needed some time during 1980-85 and the first draft of AST.396 to cover it was prepared in July 1970. Studies to the AST were to be based around an operational scenario foreseen, essentially, within a European war. Such a conflict was expected to see many thousands of Soviet tanks moving *en masse* across the European countryside. NATO could not afford to build the vast number of tanks needed to counter this but aircraft could stop the procession and it was hoped that AST.396 might clarify the types that would be best suited for the job. (The 30-year rule will keep 1970s Government records closed for some time yet; consequently, papers describing the political side to AST.396 and the Ministry's opinions of the proposed designs are inaccessible.)

AST.396

To meet the full threat, including enemy ground forces operating at night and in poor weather, a close support aircraft that could operate effectively in such conditions must inevitably be equipped with comprehensive and advanced avionics. This was likely to be technically complex and expensive and the Government might not be able to afford to provide a worthwhile force of such aircraft. The Air Staff hoped to resolve this problem by creating a composite close support force comprising a relatively small number of complex aircraft capable of operating at night and in adverse weather and a larger number of less complicated and relatively inexpensive machines capable only of visual attack and reconnaissance. It was intended that the former could be met by MRCA while the simpler machine would probably be a new design.

This second type should be a single-seat single-engine layout although a cost-effective multi-engine installation would be considered. Simplicity was paramount and all possible steps were to be taken to ensure that cost and complexity were minimised. The aircraft would serve primarily in the NATO area (i.e. Europe) and should also be capable of effectively performing a secondary role of battlefield air defence to destroy enemy strike, recce, close air support and fighter aircraft operating at low altitude in the battle area. The basic AST mission called for a battlefield interdiction sortie 60 miles (96km) behind enemy lines with six cluster bombs or Matra pods, two Sidewinder or Taildog missiles and two internal cannon. Dash Mach number was 0.9 and an initial CA Release for in-service use was required by last quarter of 1980 with full CA Release a maximum of one year later.

Studies to AST.396 occupied both BAC and HSA throughout the first half of the 1970s and the proposals show there was some doubt as to just how simple the aircraft should be. A certain amount of advanced avionics would still be needed together with some sophisticated weapons (including air-to-air) and, most probably, a STOVL or STOL capability. Even the possibility of using remotely piloted vehicles (RPVs) was considered and extensive studies of these types were made at HSA Brough, and at BAC Warton under project numbers P.75 and P.80 to P.85. HSA Kingston's work embraced versions of the HS.1184 and HS.1185 (see Chapter 10) and the HS.1186 and HS.1187 Harrier developments, although these particular projects were not originally designed to it.

In March 1972 BAC Warton completed a massive Feasibility Report to AST.396 Issue 1 covering a large range of parametric studies of all manner of shapes and sizes; much of the work was intended to see what advances could be made with the Jaguar. Overall Jaguar developments were covered by P.69, solutions using a Pegasus engine P.70 and lift engine solutions P.71; other possibilities spanned a size range from the Strikemaster Mk.87 (developed from the Jet Provost trainer) to the MRCA, plus the P.66, but much of the latter came outside the AST.396 study contract. The report concluded that Jaguar's life could be extended well into the 1980s by fitting composite fibre components and introducing other advances, but the most worthy improvement was increased thrust which completely transformed the aircraft's performance up to the levels of AST.396.

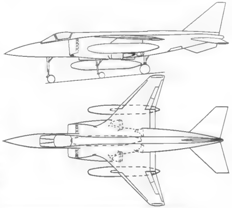
BAC P.69

This covered conventional Jaguar developments in the 30,000lb to 35,000lb (13,608g to 15,876kg) weight range with increased thrust and improved high lift. Work began with comparatively simple, relatively short-term modifications which, whilst not meeting all the AST's limits in full, might well offer a cost-effective solution. More extensive changes were also studied since the conversion of existing airframes into 'boiler plate' prototypes was expected to be a fairly quick and cheap process. There were five variants of P.69.

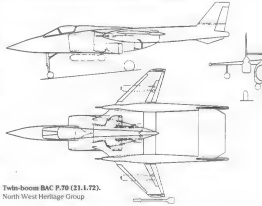
1 The existing Jaguar with modified avionics to cater for AST.396 missions. Take-off weight 29,258lb (13,271kg).
2 The existing Jaguar with uprated Adour Stage 1 or 2 engines and take-off weight of 31,782lb (14,416kg). Considerable importance was attached to uprating the propulsion system and there was great scope to increase the Adour's thrust, in stages, to a maximum reheat figure of 9,430lb (41.9kN).
3 Adour Stage 2 engines plus more substantial airframe developments directed at the AST. Rockets could provide a short burst of up to 10,000lb (44.4kN) of additional thrust.
4 A further development of 3. featuring a redesigned wing of 5% t/c ratio and a straight trailing edge; all-up-weight 36,402lb (16,512kg), internal fuel 8,690lb (3,942kg).
5 A tentative development featuring two RB.199-34R or American General Electric YJ-101 engines of about 15,000lb (66.7kN) and 14,300lb (63.6kN) reheated thrust respectively. In both cases the fuselage needed widening and deepening to accommodate the larger intakes and engines, the engine installation itself would need considerable redesign, a stronger undercarriage was essential and Variant 4's wing would be used. The RB.199 variant's all-up-weight was 35,476lb (16,092kg), internal fuel 10,180lb (4,618lit).

BAC P.70

This series utilised a vectored thrust Pegasus engine for lift and forward propulsion. The designs offered a much simpler approach than multi-engine types but there were penalties including extra drag and a higher fuel consumption. The studies used the Pegasus 15-03 with PCB but an alternative was the RB.422-04 with PCB, an entirely new proposal based on 1980 technology, smaller than the 15-03 but similar in layout. Installation problems and drag penalties were such that the aircraft was only just supersonic with PCB and could not be supersonic without it. PCB brought problems with airframe design and meant that the front nozzles now formed an integral part of the engine change unit, whereas on non-PCB Pegasus marks these were airframe mounted. To ensure that the engine could be 'dropped-out' as requested in AST.396, all of the structure in line with or below the nozzles had to be removable, which left just two relatively shallow fuselage sides and the wing slot floor to carry primary loads. Therefore, load-carrying cowl doors were also provided.

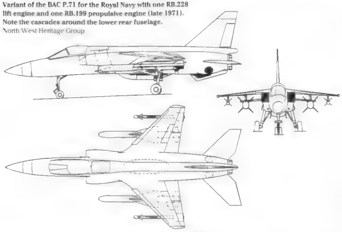


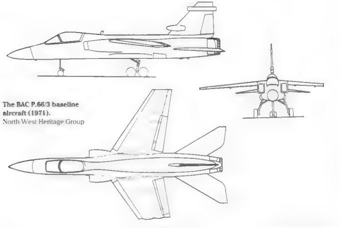
The first BAC P.70 sketch which formed a basis for detailed design. For the ferry mission, three 265gal (1,205lit) long-range fuel tanks were mounted on inboard wing pylons and a centreline pylon (1971).
North West Heritage Group



Twin-boom BAC P.70 (21.1.72).
North West Heritage Group

Variant of the BAC P.71 for the Royal Navy with one RB.228 lift engine and one RB.199 propulsive engine (late 1971). Note the cascades around the lower rear fuselage.
North West Heritage Group





The BAC P.66/3 baseline aircraft (1971).
North West Heritage Group

The first P.70 drawing used many Jaguar or modified Jaguar parts and formed the basis for detailed design. It had a Jaguar S nose and front fuselage (with some internal redesign) and a French Jaguar M nose leg. A new centre fuselage had large Harrier-style intakes and outrigger undercarriage legs located in fairings forward of the PCB nozzles (which avoided long tip-mounted outriggers). Two developed Aden guns were mounted forward of the outriggers and stores could be carried up to four abreast aft of the nosewheel bay and on underwing pylons. The rear fuselage spine, wings, fin and tailplane were similar to Jaguar, although wing t/c was increased to 7%, and a '1980 technology level' aircraft would make extensive use of composite materials and fly-by-wire (computer-controlled flight). A naval version carried two Martel ASMs on the inboard wing pylons and sported a longer nose that housed a 27in (68.6cm) diameter radar dish instead of the laser.

To overcome the engineering problems associated with installing a Pegasus within a conventional fuselage, the most promising alternative configuration was a twin-boom layout. Advantages included keeping the rear exhaust nozzles closer together, the fuselage structural loads were drastically changed and were more compatible with the engine bay shape and size, and a conventional undercarriage could be used which greatly eased the problems of exhaust gas impingement and debris deposition. Changes from the basic P.70 included a centre fuselage modified so that fuselage and engine loads were carried directly to the wing box and a centre wing section that had a straight trailing edge and rear spar. The booms were area-ruled and housed the main wheels, fuel tanks and guns and the fins carried a slab all-moving tailplane. Four stores could be carried across the fuselage aft of the nosewheel bay, singles were loaded on the outboard pylons and the aircraft had tip-mounted AAMs.

BAC P.71

It was felt that the technical feasibility of the aircraft type which used separate lift engines had been well established by experience accumulated from the Short S.C.1, Dassault Mirage IIIV and VFW Fokker 191B research aeroplanes, but the economic and operational factors had still to be clarified. The economics had been made more attractive by progressive developments in engine technology, particularly with reductions in lift engine weight, while the Kestrel and Harrier (which did not use lift engines) had helped to clarify a good deal of the operational aspect.

The jet lift vehicle introduced some special design factors, for example a low-speed control system was needed which, by necessity, had to be a reaction system of some kind. A critical aspect of all jet lift V STOL projects was nozzle location; the factors involved were jet-induced interaction effects, airframe and undercarriage heating (particularly near the ground), re-ingestion of the efflux (again particularly near the ground), vulnerability to battle damage, thrust balance to minimise pitching, noise and vibration levels, ground erosion and debris scatter, and the consequences of engine failure. P.71 was specifically aimed at reducing jet-induced lift losses, re-ingestion and heating effects. BAC Warton preferred this solution rather than the single vectored thrust engine since 'greater freedom and adaptability is possible which can be used to considerable advantage'.

Rolls-Allison XJ.99 lift units were used although an alternative engine offering '1980' standards was the new advanced RB.227-01 proposal. The lift and propulsive engines were located respectively well forward and well aft of the aircraft's CofG which gave some advantages – the centre fuselage was left free for fuel, main wheels, stores, ventral packs and guns whilst this also helped the aircraft's weight balance. Datum P.71 was a long-term Jaguar development fitted with two RB.199-34Rs and two XJ.99s for an all-up-weight of 37,749lb (17,123kg). It resembled Jaguar quite closely but included the nose, wing, fin, tail and Jaguar M undercarriage of the Pegasus-powered P.70.

However, the centre fuselage and lift engine bay contained little Jaguar. This had been lengthened by 30in (76.2cm) and almost completely redesigned to accommodate two lift engines fitted with blade deflectors and inclined 15° from the vertical. Both intakes and ducts were 50% larger than Jaguar's to allow for the increased mass flow of the RB.199s (the fixed pitot intakes had splitter plates), internal fuel was increased and a modified M-type undercarriage kept the belly free for weapons or recce packs. The reaction control system used air bled from the lift engines. The rear fuselage was similar to Jaguar but it was broader and deeper to accommodate the larger engines with their rotating cascades, the latter supplying the main engines' vertical thrust.

There were some smaller alternatives. One had a single Pratt & Whitney F.100 with twin cascades and twin XJ.99s; an even lighter arrangement had a single YJ-101, two XJ.99s or RB.227s and a simplified structure and systems for an all-up-weight of 26,892lb (12,198kg). Another design had an even smaller wing, fuselage length reduced by 3ft (0.9m), one RB.199-42R (the engine developed for the MRCA fighter) and one RB.228-02 with central blade deflector (a scaled-up RB.227 to retain the thrust balance). The centre and rear fuselage could accommodate large ventral packs and, after the load-carrying access doors were removed, the complete engine and cascades could be 'dropped out'. The wings were based on Jaguar developments and the project had a Jaguar-style nose with its laser, but a naval version would have a different nose to take a 24in (61.0cm) diameter radar dish. This final aircraft was small enough to eliminate wing folding and could carry two Harpoon ASMs on the inboard pylons and two Sidewinder AAMs outboard.

BAC P.66

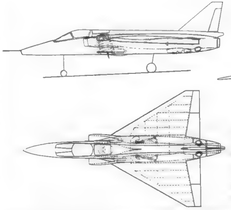
Here the 1971 PANNAP P.61 family (see Chapter 13) formed a datum before the three basic designs, P.66/1, P.66/2 and P.66/3, were split into a range of parametric studies. P.66/1 had an unreheated Adour RT.172-06, an appropriately reshaped fuselage and intake plus a set of avionics that generally met the needs of AST.396. The supersonic P.66/2 had an Adour Stage 2 of 9,550lb (42.4kN) reheated thrust, the same avionics and an all-up-weight of 20,287lb (9,202kg). P.66/3 used a single RB.199-34 MRCA engine but there was no chance of this aircraft being sized to meet all of the AST's limits. Hence the parameter most closely examined was take-off weight and a figure of 25,000lb (11,340kg) was calculated to meet the interdiction mission 60 miles (96km) behind enemy lines.

BAC P.72, P.73 and P.74

Warton also undertook numerous alternative studies to AST.396 Issue 1. These included the P.72 series of all-new designs (some had delta wings), the P.73 lightweight aircraft with swing wings, and further Jaguar developments fitted with new engines (the P.74).

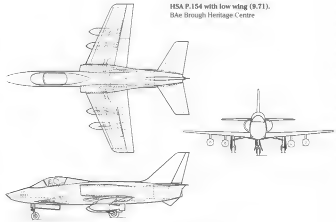
HSA Brough P.154

In 1967 Brough began a study of very light ground attack aircraft with its P.146 project. The P.154, prepared to AST.396, moved on from this early work and both low and high-wing versions were suggested; the latter would carry stores more easily and offered better aerodynamics but the wing itself, and the fuselage, were essentially the same. There were alternative versions with twin Adours, but all of the designs carried a maximum of four 1,000lb (454kg) bombs under the wings and two cannon in the lower front fuselage.

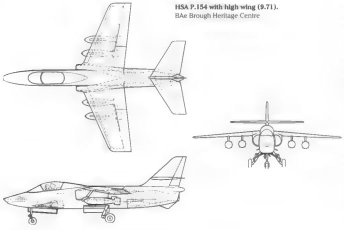


Variant of the BAC P.72 small delta aircraft (1971). Span 24ft (7.3m), length 42ft 2in (12.9m), wing area 320ft² (29.8m²), t/c ratio 7%. Note the two cannon in the lower fuselage, a lift jet behind the cockpit and cascades on the lower rear fuselage.
North West Heritage Group

Artist's impression of the HSA Brough P.154.
BAe Brough Heritage Centre



HSA P.154 with low wing (9.71).
BAe Brough Heritage Centre



HSA P.154 with high wing (9.71).
BAe Brough Heritage Centre

HSA Brough P.153 and HS.1190

A more substantial proposal was the P.153 small combat aircraft begun in 1969. This was intended to be more of a fighter than a strike aircraft and results from actual and simulated air combat led Brough to conclude that the majority of combat would be in the subsonic or low supersonic speed regime at low to moderate altitudes. P.153 used a single RB.199 while the application and extension of techniques in boundary layer control over full-span leading-edge and trailing-edge flaps for high lift, as developed for the Buccaneer and Phantom, provided good STOL capability; the BLC air was taken from the RB.199's LP compressor. To suit the size and scale of P.153, and cut weight, AI radar was excluded and the proposed AI system was based on an infra-red sensor. A laser ranger would be used for ground attack.

P.153's all-round capabilities ensured that attention was given to battlefield support operations and a version designated HS.1190 was therefore included in HSA's AST.396 studies; in fact it offered the highest low-level speed of any HSA aircraft designed to meet the Target's conditions. By February 1972 P.153 itself was considered a separate project since it was essentially a fighter with close air support capability. The advanced technology RB.199 and simple pitot intake made possible a 33% reduction in aircraft size compared to previous-generation engines; reheat and a thrust reverser were provided. Great attention was given to combat manoeuvrability but, apart from its BLC system, P.153 was fairly conventional and utilised current materials and manufacturing techniques. The mid/high wing position helped to minimise transonic drag and the 5,500lb (2,495kg) of internal fuel permitted an interception 130nm (241km) from base; two 100gal (455lit) drop tanks would increase range to over 220nm (407km).

With fighter armament (six Sidewinder AAMs or SRAAM 100s) and fuel for combat at 100nm (185km) radius, P.153 weighed 19,084lb (8,657kg); as a ground attack aircraft with four 1,000lb (454kg) bombs and the same fuel it weighed 23,568lb (10,690kg). A pair of cannon were housed in the lower forward fuselage and there were seven weapon stations, comprising two wing tip mounts and five main pylons (two under each wing and one beneath the mid-fuselage point) for bombs, missiles or drop tanks. Expected RB.199 developments would increase thrust to 20,000lb (88.9kN) and push the top speed up to Mach 1.8 at altitude; a variable geometry intake would have permitted Mach 2 but at the expense of low-speed and transonic performance. Low-level penetration speed would be Mach 0.75, escape speed in reheat Mach 1.1.

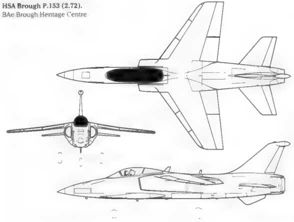
It was thought that a 1972 start date could bring a prototype first flight late in 1976 and put the aircraft in squadron service by 1981. Six pre-production machines were needed for the bulk of the development and clearance work which would take place from first flight in 1978 until 1981. P.153 was pushed by Brough for several years but the British Government did not take it up because there was no fighter requirement. As a consequence it was eventually abandoned. In 1975 P.153 was succeeded by the pure fighter P.159 which, apart from an increase in wing area, looked very similar. This, as the HS.1204, was proposed to AST.396's replacement, AST.403, which established air combat as the primary role.

HSA HS.1189 and HS.1192

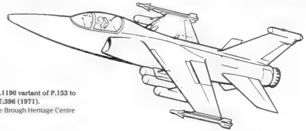
P.153/HS.1190 required a 2,500ft (762m) runway and appeared to be a good cost-effective answer to the AST, but there were two more HSA Issue 1 projects. The HS.1189 was the most simple and used an unreheated RB.199 or reheated Adour but it needed a 3,500ft (1,067m) runway which counted against it. Span was 34ft 1in (10.4m), length 39ft 8in (12.1m), all-up-weight 19,213lb (8,715kg), action radius 110nm (204km), low-level penetration speed Mach 0.78 and escape speed (dry thrust) Mach 0.83. It had two wing tip Sidewinders and four underwing pylons that could load six bombs.

HSA Kingston principally looked upon its AST.396 work as explorations in V/STOL, but the company did not consider itself a V/STOL specialist; witness the Hawk trainer of which one variant, the HS.1182-74, was offered to the AST as a lower-capability option. The supersonic HS.1192 went to the other extreme in that it fully met all of the requirements but, for the 110nm (204km) radius, weighed 41,960lb (19,033kg). It also had a very complex powerplant which comprised twin RB.231 propulsion units of 12,800lb (56.9kN) reheated thrust each (one per side) with twin tailpipes and a pair of cascade nozzles with diverters behind, and two RB.277 lift units behind the cockpit. Low-level penetration speed using dry thrust was estimated to be Mach 0.9, escape speed (reheat) Mach 1.1. (A cascade is a deflector made from several parallel aerofoil-shaped vanes which is placed inside the nozzle to give a smooth, redirected airflow. In contrast, a diverter is a door that closes across the jet pipe to divert the gas flow from one direction to another; it works a bit like a thrust reverser and blocks the jet pipe so that the exhaust is diverted to the nozzle.)

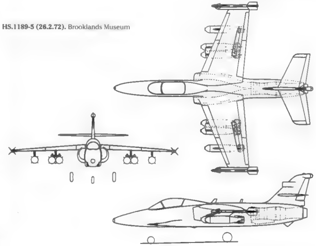
AST.396 Issue 1 was intended to provide guidelines for wide-ranging parametric studies which were aimed at defining the broad characteristics of an aircraft to replace Harrier and Jaguar in the 1980s. These essentially revealed that, while technically feasible, the cost of developing an aircraft to meet the AST in full could be unacceptably high. It was established that the new aircraft must have a priority requirement to operate at night and in poor visibility conditions but otherwise it appeared that its performance need only be similar to Harrier and Jaguar. Consequently Issue 2, produced in the first months of 1973, looked at exploiting the development potential of either Harrier or Jaguar while concentrating on night and poor-vision capability. CA Release for in-service use was required by 1987 and a maximum speed of 450 knots (518mph/834km/h) at 100ft (30.5m) was requested. Top speed at height was left open and most of the other limitations were unchanged from Issue 1; armament was to be six BL.755 cluster weapons, a total of 6,000lb (2,722kg) of external stores plus two short-range infra-red homing AAMs.



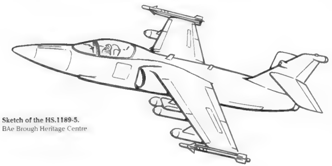
HSA Brough P.153 (2.72).
BAe Brough Heritage Centre



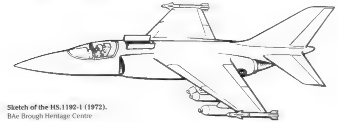
HS.1190 variant of P.153 to AST.396 (1971).
BAe Brough Heritage Centre



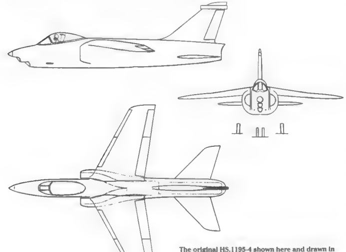
HS.1189-5 (26.2.72). Brooklands Museum



Sketch of the HS.1189-5.
BAe Brough Heritage Centre



Sketch of the HS.1192-1 (1972).
BAe Brough Heritage Centre



The original HS.1195-4 shown here and drawn in about August 1974 was adapted with modifications to AST.396 Issue 2. Brooklands Museum

Rather less detail is available for most of the BAC and HSA AST.396 Issue 2 designs. Warton suggested variants of the MRCA Tornado (covered by P.76 which included a single-seat aircraft), yet more variants of Jaguar ranging from minimum-change versions (P.77) to designs with new wings including VG (P.78) or with a new fuselage and the existing Jaguar wing (P.79). Later the P.86 long-term Jaguar development was suggested to AST.396 Issue 3 but this work soon spilt over into the replacement AST.403.

HSA Kingston HS.1195
Several versions of this project were drawn from June 1974 and a modification of the HS.1195-4 was intended for AST.396 Issue 2. It had side-by-side sensors beneath the radome, one cannon each side beneath the cockpit, three-piece slats and flaps, tip-mounted Sidewinders, three underwing BL.755s per side, two tandem BL.755s beneath the fuselage and twin-wheel main legs. Span was 34ft (10.4m) and length 47ft (14.3m); power was supplied by an RB.238-10.

HSA Brough HS.1197
During 1974, after a request from the MoD, Brough assessed the S Mk.2B (RAF) Buccaneer against AST.396 Issue 2. The AST also desired that the battlefield/short-range interdiction and recce roles might be performed at longer ranges and the assessment indicated that relatively few modifications were needed to enable the Buccaneer to meet the AST in full. The most essential changes were a better take-off and landing performance and an improved nav/attack system. The aircraft was designated HS.1197 and with an early start it could be put into service in 1981. Dimensions were standard Buccaneer and the project was very similar to Brough's P.157.

Take-off and landing roll distances of under 3,000ft (914m) were needed and Brough felt the most cost-effective solution was to utilise quick-acting blow for take-off and install a braking parachute for landing. No problems were envisaged because a number of quick-acting blow take-offs had already been performed, with encouraging results, while a brake parachute had been fitted to some early Buccaneer prototypes. Buccaneer was probably large enough to accommodate all of the possible night sensors for nav/attack including both FLIR and LLTV. Two gun packs were fitted to the lower fuselage beneath the intakes and, to accept the heavier loads, a tandem two-wheel main undercarriage was introduced. Radius of action was 240nm (444km), penetration speed Mach 0.68 and escape speed Mach 0.88. This aircraft was intended to operate in conjunction with the very light HS.1182-74 or P.154 class of aircraft and to deal with the more extreme parts of the AST.

Brough's Roy Boot noted that 'there was a good deal of alarm in the industry that the requirement [AST.396] was too restricted in the scope of the roles specified, and that it was too ambitious in some of the technological solutions needed to fulfil the envisaged operations'. He felt that a go-ahead for such a project might prove financially disastrous and, despite the wished-for low-cost option, some significant advances in technology would still be needed to accomplish the job.

The AST.396 designs range from the most simple to quite complex aeroplanes. Roy Boot reported that 'it was with considerable relief that we learned of the withdrawal of AST.396, with the subsequent issue of AST.403 which placed the primary emphasis on the air-to-air role'. AST.403, first issued in 1975, was the start point for what became Eurofighter Typhoon; the rest of the story is described in the companion *British Secret Projects: Fighters*. In fact, until around 1985, the heavy drain on the Air Vote by variants of Tornado meant that little money would be available for any other new manned fixed-wing air projects. In this climate the Air Force Department OR Branch could do little with AST.396 other than assign BAC and HSA with small exploratory tasks designed to investigate new technology and equipment, such as fly-by-wire or incorporating the 1553B databus. Today the RAF still uses the Harrier GR Mk.7 and upgraded versions of Jaguar.

Future Offensive Air System (FOAS)

So what of the future? Reports suggest that the RAF will run its Tornado GR Mk.4 fleet until 2018 but work has been ongoing since at least 1995 to find a replacement. At the end of that year initial studies were completed for a Future Offensive Aircraft (FOA) to a guideline requirement SR(A).425. In 1996 the MoD and BAe completed a Pre-Feasibility study which looked at 'a range of aircraft-based weapon system concepts to determine their capability, cost timescale and technical risk'. A top-level study was also carried out by the MoD into its future long-range offensive capability – would it still be needed? Since the end of the Cold War, RAF operations have indeed tended to be long-range affairs.

In 1997 the MoD launched a full Feasibility study, the project having been redesignated in late 1996 the Future Offensive *Air System* (FOAS) to embrace non-piloted aircraft (Uninhabited Air Vehicles or UAVs flown by 'pilots' on the ground) and missiles. Options included an enhanced Eurofighter with a thicker wing to increase fuel capacity, a new off-the-shelf single or two-seat stealth combat aircraft, a UAV or conventional air-launched cruise missiles released at long range from a transport aircraft. It was envisaged that several UAVs could be produced, fitted with

FOAS. One solution to the requirement is a mix of manned aircraft, unmanned UAVs and conventional air-launched cruise missiles. Published PR artwork may not necessarily be based on current thoughts. BAE Systems

either intelligence, surveillance, reconnaissance or combat equipment, which would operate alone or in close co-operation with manned aircraft. Contracts were placed with industry and the Defence Evaluation and Research Agency while the French Defence Ministry contributed to a Technology Demonstration Programme that covered the computer modelling of weapon systems. One concern surrounding a UAV type centres on training – will it be possible to train realistically with such weapons so that we know how they are going to work in a conflict?

The Technology Demonstration Programmes also encompassed systems, avionics, cockpits and weapons integration. Today, instead of manual analysis, FOAS can be designed as a computer model so it is much easier to change and test different shapes or modifications. However, should an all-new manned FOAS aircraft be chosen, the most favoured layout is likely to remain secret for some time. Hopefully there will be an FOAS Demonstrator Aircraft (an EAP Mk.2) built and flown in the not too distant future to test the most important technical advances that the full weapon system will need. Work on developing the FOAS Operational Requirement was ongoing during 1999.

It is significant that the UK aerospace and defence industry can still consider developing a type such as FOAS. Back in the late 1960s and early 1970s, when the Americans produced their F-14 to F-18 series of fighters with such relative ease and speed, there was serious political pressure from the UK Treasury and US industry for Britain to buy American. This succeeded with orders for the Phantom fighter and C-130 Hercules transport but the multi-national Tornado project saved the RAF and UK industry from being completely dominated in the fighter and strike aircraft field. Had that not been the case, the military side of UK aerospace could have gone to the wall. FOAS, or whatever succeeds it, and a significant design share in the American Joint Strike Fighter, will hopefully secure this valuable position for some time to come.

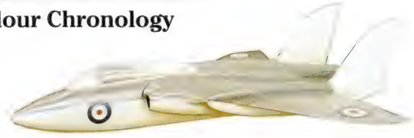
The end of the Cold War and its potential conflict between major powers may mean that the need for even the US to develop new and very expensive heavy strategic bombers no longer exists. Unfortunately the politics of the day, localised wars, terrorists and political extremists, will ensure that the need for strike and attack aeroplanes has to stay. Will such aircraft have a pilot? – we must wait and see. Any new UK bomber is going to be a hugely political animal and funds for it might be difficult to justify but, over the last dozen years, the RAF's bomber force has been involved in several conflicts and in due course it will need replacing. (Only recently, American B-52Hs have dropped large quantities of bombs over Iraq – it is always unwise to try to predict the future of aerospace).

Cost will probably drive any new project rather than technology, which in the past has often been the dominant factor. The Royal Aeronautical Society's Keith Mans has said that Eurofighter Typhoon was 'one of the last aircraft produced with the types of funding that Treasuries could be persuaded to part with during the Cold War'. Only time will tell if the RAF will get its Tornado replacement but perhaps one day, rather than Harriers and Tornados, the Cotswold landscape near my home will see large unmanned aeroplanes passing over at low level and high speed. Politically, financially and technically, that would be some achievement.

AST.396 Projects – Estimated Data

Project	*Span ft in (m)*	*Length ft in (m)*	*Wing Area ft² (m²)*	*t/c %*	*All-Up-Weight lb (kg)*	*Powerplant Thrust lb (kN)*	*Max Speed Height mph (km/h) ft (m)*	*Weapon Load lb (kg)*
BAC P.70 (Basic Configuration)	29 6 (9.0)	51 6 (15.7)	not given	7	37,100 (16,829)	1 x Pegasus 15-03 with PCB	Mach 1+	2 x 30mm Aden cannon, various stores
BAC P.70 (Twin Boom)	29 2 (8.9)	51 0 (15.5)	not given	7	c36,000 (16,330)	1 x Pegasus 15-03 with PCB	Mach 1+	2 x 30mm Aden cannon, 6 x bombs or other stores, 2 x Sidewinder AAMs
BAC P.71 (Smallest size, Naval version)	22 11 (7.0)	43 7 (13.3)	not given	7	c26,000 (11,794)	1 x RB.199-42R, 1 x RB.228	Mach 1+	2 x 30mm Aden cannon, 6 x bombs, 2 x Harpoon ASMs, 2 x Sidewinder AAMs
BAC P.66/3	31 8 (9.7)	43 0 (13.1)	not given	not given	21,780 (9,879)	1 x RB.199-34 c15,000 (66.7) reheat	Mach 1+	?
HSA P.154	30 0 (9.1)	37 6 (11.4)	194 (18.0)	not given	15,692 (7,118) low wing, 16,065 (7,287) high wing	1 x RB.199 no reheat	High subsonic(?)	2 x cannon, 4 x bombs
HSA P.153	24 8 (7.5)	43 8 (13.3)	185 (17.2)	not given	23,500 (10,660)	1 x RB199-34R 15,300 (68.0) reheat	Mach 1.2 at low level, Mach 1.6 at height (both with AAM)	2 x 30mm Aden or DEFA cannon, 5 x 1,000 (454) bombs 7 x 540 (245) or BL755 cluster bombs, 8 x RP launchers
HSA HS.1197	44 0 (13.4)	63 5 (19.3)	508.5 (47.3)	9.25 to 6	49,075 (22,260)	2 x RB 168-78 11,560 (51.4)	670 (1,078) at sea level	2 x cannon, 6 x BL755 or other stores

British Secret Bomber Colour Chronology



Westland's M.148T two-seat naval strike aircraft featured a distinctive twin-fin configuration.

Westland P.1061 model by Joe Cherrie Snr. This high-speed jet fighter-bomber had a large nose intake and was powered by two MetroVick F.2/4 Beryl axial engines mounted side-by-side in the fuselage.

The Handley Page HP.99 low-altitude bomber had its four Avon RA.14 engines paired in low-slung underwing pods. Note the Victor-like cockpit glazing. Artwork by Pete West

In 1999 a Canberra was repainted in the colours and markings of the first prototype to celebrate the fiftieth anniversary of its first flight. North West Heritage Group

The distinctive lines and large bomb bay of the Avro Vulcan are shown to good effect in this flypast. Bob Munro

Vickers Valiant prototype WB215 comes in to land at a Farnborough Air Show. Eric Morgan Collection

Photographs on the opposite page

Blackburn Buccaneer S Mk.2 XV350 was used as a development aircraft for the TV-guided Martel air-to-surface missile and is seen in 1969 carrying some trial rounds. BAe

Seen here in 1989, XL190 was one of the Handley Page Victor B Mk.2s converted to tanker configuration. Tony Butler Collection

The first BAC TSR.2, XR219 seen at Boscombe Down in 1964. This was the only example to fly. North West Heritage Group

Model of the English Electric P.10, the company's response to Specification R.156T for a supersonic all-weather high-altitude reconnaissance aircraft. Ken Hunter Collection

Model of the Bristol 204 tactical strike/reconnaissance aircraft to GOR.339. This view shows the distinctive 'Gothic' wing and foreplane.

Fairey's response to GOR.339 was a canard 60° delta, the structural and aerodynamic features of which owed much to experience gained from the Delta II research aircraft.

Hawker Siddeley's group submission to GOR.339 was based heavily on the Hawker P.1129 and Avro 739 and featured improvements such as an 'aera rule' fuselage. Artwork by Pete West

The DH.127 tailless delta multi-purpose strike fighter would have operated from *Ark Royal* size aircraft carriers. This aircraft could stay on combat air patrol for up to four hours. Artwork by Pete West

A simple and rugged design, the Avro 727 daylight ground attack aircraft was powered by a Bristol BE.26 Orpheus engine. The design drew heavily on the Avro 726. Artwork by Pete West

Surviving Harrier GR Mk.1s were retrofitted with the Ferranti Type 106 LRMTS which accounted for the elongated nose of what was known as the Harrier GR Mk.3. Bob Munro

BAe Harrier GR Mk.5 ZD318 displays the large strakes under the fuselage which, with a retractable 'cross-dam', helped to increase the aircraft's vertical lift capability over previous versions. Eric Morgan Collection

BAe Harrier GR Mk.7 ZD461 seen in low-speed hover mode. BAe

Photographs on the opposite page:

Two Short Seamews (prototype XA213 nearest) pose for the manufacturer's official cameraman. The unpainted aircraft behind is very likely the first prototype, XA209, which dates the photo to about 1954/55. Shorts

BAe Nimrod MR Mk.2 XV254. Note the pairs of Sidewinder AAMs for air defence. Avro Heritage Centre

A Jaguar GR Mk.1B armed with a centreline 1,000lb (454kg) bomb and equipped with overwing launch rails for Sidewinder AAMs. Bob Munro

The Tornado GR Mk.1 can carry up to nine BAe ALARM missiles, three of which can be seen on this aircraft's underfuselage weapon stations. BAe

Above left and right: Two views of the AFVG model with its wings set to their extreme limits of sweep. BAE Systems

Below: Spectacular view of Panavia Tornado GR Mk.1 ZA412 of No 16 (Bomber) Squadron in full reheat. BAe

Glossary

A&AEE Aeroplane and Armament Experimental Establishment, Boscombe Down.
AAM Air-to-air missile.
ACAS(OR) Assistant Chief of the Air Staff (Operational Requirements) [Air Ministry post].
ACAS(TR) Assistant Chief of the Air Staff (Technical Requirements) [Air Ministry post].
ACM Air Chief Marshal.
ACT Active control technology.
ADARD Assistant Director of Aircraft Research and Development [Ministry of Supply post].
AI Air Interception.
ALARM Air-launched anti-radiation missile.
AMRAAM Advanced medium-range air-to-air missile.
anhedral Downward slope of wing from root to tip.
AoA Angle of attack, the angle at which the wing is inclined relative to the airflow.
AP Armour piercing.
area rule The optimisation of longitudinal cross-section area distribution for minimum wave drag.
AS Armstrong Siddeley.
A/S Anti-submarine.
ASM Air-to-surface missile.
aspect ratio Ratio of wing span to mean chord, calculated by dividing the square of the span by the wing area.
ASR Air Staff Requirement.
ASRAAM Advanced short-range air-to-air missile.
AST Air Staff Target.
ASTOVL Advanced short take-off & vertical landing.
ASV Anti-surface vessel.
AVM Air Vice-Marshal.
AWA Armstrong Whitworth Aircraft Ltd.
BAC British Aircraft Corporation.
BAe British Aerospace (today BAE Systems).
boundary layer control Control of the layer of air which is in immediate contact with the aircraft's surface to increase lift, reduce drag and/or improve control under extreme flight conditions.
BP Boulton Paul Aircraft.
BS Bristol Siddeley.
CA Controller of Aircraft (UK).
CAD Computer-aided design.
CAP Combat air patrol.
CAS Chief of the Air Staff [Air Ministry post].
CCV Control-configured vehicle.
CinC Commander in Chief.
chord Distance between centres of curvature of wing leading and trailing edges when measured parallel to the longitudinal axis.
CofG Centre of gravity.
Critical Mach Number Mach number at which an aircraft's controllability is first affected by compressibility, i.e. the point at which shock waves first appear.
CS(A) Controller of Supplies (Air).
CTOL Conventional take-off and landing.
DARD Director of Aircraft Research and Development [MoS post].
DC Depth charge.
DCAS Deputy Chief of the Air Staff [Air Ministry post].
DCNR Deputy Chief Naval Representative (Air) [MoS post].
DDARD(S) Deputy Director of Aircraft Research and Development (Supply). [MoS post].
DDGSR(A) Deputy Director General of Scientific Research (Air) [MoS post].
DDOR Deputy Director of Operational Requirements.
DGSR Director General of Scientific Research [MoS post].
DGTD(A) Director General of Technical Development (Air) [MoS post].
DH de Havilland.
dihedral Upward slope of wing from root to tip.
DMARD Director of Military Aircraft Research and Development [MoS post].
DOR(A) Director of Operational Requirements (Air).
DTD Director of Technical Development [MoS post].
EAP Experimental Aircraft Programme.
EAS Equivalent airspeed (a rectified figure incorporating a compressibility correction).
ECM Electronic countermeasures.
EE English Electric.
FAA Fleet Air Arm.
FBW Fly-by-wire.
FLIR Forward-looking infra-red.
HAL Hawker Aircraft Limited.
HC High-capacity bomb.
HE High explosive.
HMG His/Her Majesty's Government.
HP Handley Page.
HSA Hawker Siddeley Aviation.
HSG Hawker Siddeley Group.
HTP High-test peroxide (rocket fuel).
IAS Indicated airspeed.
incidence Angle at which the wing (or tail) is set relative to the fuselage.
IR Infra-red.
ISA International Standard Atmosphere.
ITP Instruction to Proceed.
jet flap An air jet placed at the wing trailing edge where the flow is induced around a strongly curved path to give very large lift coefficients.
kinetic heating Heating of the airframe by friction created by its passage through the air. This can take the surface temperature towards the heat-resisting limit of the constructional materials.
LE Leading edge.
LERX Leading-edge root extensions.
LLTV Low light television.
LRMTS Laser ranging and marked target seeker.
MAP Ministry of Aircraft Production – created May 1940 to relieve the Air Ministry of its role of procuring aircraft and the equipment and supplies associated with them. Functions transferred to the Ministry of Supply in 1946.
MBB Messerschmitt-Bolkow-Blohm.
MC Medium-capacity bomb.
MetroVick Metropolitan Vickers
MinTech Ministry of Technology – created in 1964 to cover computers, telecommunications and machines tools. Extended in 1966 to embrace other industries including merchant shipbuilding. In 1967 it merged with the MoA but a few years later the military aviation side was removed to be covered by the MoD Procurement Executive (MOD[PE]).
MoA Ministry of Aviation – created October 1959 when the civil aviation functions of the Minister of Transport and Civil Aviation were transferred to the Ministry of Supply and merged.
MoD Ministry of Defence – created late 1940s to co-ordinate the policy of the three Armed Services. In April 1964 the MoD was reconstituted to absorb the functions of the Air Ministry, Admiralty and War Office, the Air Ministry (the civilian body that had governed the RAF) ceasing to exist.
MoS Ministry of Supply – created August 1939 to provide stores used by the RAF (and Army and Navy). Disbanded and reconstituted as the Ministry of Aviation in 1959.
MoU Memorandum of Understanding.
MRCA Multi-Role Combat Aircraft (later Tornado).
MWDP United States Mutual Weapons Development Programme.
NACA National Advisory Committee for Aeronautics (in America). Today is NASA, the National Aeronautics and Space Administration.
NASR Naval Air Staff Requirement.
NAST Naval Air Staff Target.
NATO North Atlantic Treaty Organisation.
NGTE National Gas Turbine Establishment (merged with RAE, 1983).
nm Nautical mile.
OR Operational Requirement.
PCB Plenum chamber burning.
PDRD(A) Principal Director of Research and Development (Air) [MoS post].
PDSR(A) Principal Director of Scientific Research (Air) [MoS post].
PDTD(A) Principal Director of Technical Development (Air) [MoS post].
PR Photo reconnaissance.
R&D Research and Development.
RAAF Royal Australian Air Force.
RAE Royal Aircraft Establishment, Farnborough (became part of DERA, the Defence Evaluation and Research Agency).
RATO Rocket assisted take-off.
RN Royal Navy.
RNVR Royal Naval Volunteer Reserve.
RP Rocket projectile.
rpm Revolutions per minute.
RPV Remotely piloted vehicle.
RR Rolls-Royce.
RSS Relaxed static stability.
RTO Resident Technical Officer.
SAGW Surface-to-air guided weapons.
SAM Surface-to-air missile.
SBAC Society of British Aircraft Constructors (now Society of British Aerospace Companies).
SR(A) Staff Requirement (Air).
SST Supersonic Transport.
STOL Short take-off and landing.
STOVL Short take-off and vertical landing.
TAS True airspeed.
t/c Thickness/chord ratio.
TE Trailing edge.
TMB Target Marker Bomb (= tactical nuclear weapon).
transonic flight The speed range either side of Mach 1.0 where an aircraft has both subsonic and supersonic airflow passing over it at the same time.
TRE Telecommunications Research Establishment, Malvern (became RSRE – Royal Signals and Radar Establishment and later part of DERA).
TT Torpedo.
US(Air) The Under Secretary of State for Air.
USAAF United States Army Air Force.
USAF United States Air Force.
USN United States Navy.
VCAS Vice Chief of the Air Staff.
VG Variable geometry.
VIFF Vectoring in forward flight.
VTOL Vertical take-off and landing.

Useful conversion factors:

x 0.093	square feet (ft²) to square metres (m²)
x 0.3048	feet (ft) to metres (m)
x 0.4536	pounds (lb) to kilograms (kg)
x 1.2	Imperial (UK) gallons to US gallons
x 1.609	miles to kilometres (km) (also for mph to km/h)
x 1.852	knots to kilometres/hour (km/h)
x 2.54	inches (in) to centimetres (cm)
x 4.5469	Imperial UK gallons (gal) to litres (lit)
÷ 225	pounds (lb) to kilonewton (kN)

A view of the first Hawker Siddeley 'P.1127' Kestrel FGA Mk.1, XS688.

Appendix One

British Bomber Projects Summary

During their years of independence, many of Britain's aircraft manufacturers became wedded to certain types of aeroplane or areas of manufacture. Hawker, for example, was a fighter specialist while Avro, Bristol, Handley Page and Vickers were usually inclined towards bigger game and built, or at least designed, many heavy bombers. Blackburn was just one manufacturer to supply aircraft to the Fleet Air Arm regularly and this was a major influence on its lines of development.

The following lists jet and turboprop-powered heavy bombers, light bombers, interdictors, strike aircraft, anti-submarine and close support aircraft, plus research types developed mainly to advance the bomber designer's art. To hold the list to manageable proportions, pure trainer and reconnaissance developments are omitted (with a few exceptions) although some designs produced as combined strike trainers do get in. In theory, all projects are 'official', despite some schemes lasting for such a brief lifetime (perhaps just a day or two) that they really have no right to be here, but sneak in as one cannot always determine which they are. For some projects little or no information is known to have survived and has probably been lost forever. Others of course are still secret. Designs produced at Brough, Kingston and Warton from about the early 1960s onwards would often cover a selection of different layouts and, from a publishing point of view, this makes life difficult since one cannot include every drawing. Hence, in such cases, only the most suitable or representative drawing is reproduced; perhaps one which has been examined in some depth or used as a baseline for other variations.

AIRSPEED

AS.69 Maritime reconnaissance variant of AS 57 Ambassador airliner, 1951. Had AS.57's high wing. AS.69A similar but wing in low position, 1951. AS.69A span 115ft (35.1m), length 82ft 6in (25.1m), all-up-weight with bomb load 60,000lb (27,216kg). Fitted with ASV radar and two gun turrets on upper fuselage.

ARMSTRONG WHITWORTH

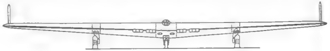
AW.50 Flying wing jet bomber: design study tendered to MAP mid 12.42. Designer 'Jimmy' Lloyd deleted fuselage to gain maximum benefit of laminar flow wing (recently developed in USA) and reduce drag; led to flying wing concept used by AWA for some years. Need for ultra-smooth surface met by construction using fairly thick light alloy skin supported by rolled corrugations of thinner gauge – skin and corrugations acted as spar flanges for taking bend and torsion and together with the webs formed a box spar which was lighter than conventional construction but with high degree of stiffness to maintain accurate profile shape. Only projections outside wing profile were crew cabin and remotely controlled twin 20mm turret behind. Design featured two fixed forward-firing 20mm cannon in wings between engines, four 4,000lb (17.8kN) MetroVick F-3 turbojets in pairs just outside each side of centre cockpit, split flaps, 'elevators' on the trailing edge near the tip, wing tip fins and rudders. Outboard movement of rudders greater through differential gearing. Estimated top speed 470mph (756km/h) at sea level, Mach 0.7 480mph (772km/h) at 30,000ft (9,144m), sea level rate of climb 3,340ft/min (1,018m/min), time to 30,000ft 14 minutes, range 1,500 miles (2,414km), all-up-weight 49,765lb (22,573kg), wing loading 27lb/ft² (132kg/m²), bomb load 12,000lb (5,443kg). Span 120ft (36.6m), wing area 2,000ft² (186m²), t/c 23.5%. Revision with span 112ft 6in (34.3) and t/c 15% to MAP 1.44. Turret deleted but thinner wing forced introduction of fuselage for crew. Length 45ft (13.7m), all-up-weight 54,183lb (24,577kg), top speed 460mph (740km/h). Project soon abandoned

AW.51 One-third scale wood glider to test aerodynamics of highly experimental AW.50, 1943.

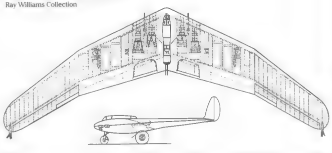
AW.52 Experimental tailless aircraft to E.9/44 to test flying wing concept (with large-chord low-drag wings) for large aircraft – bombers and civil. AW 52G scale glider flew 2.3.45. First of two AW.52 prototypes flew 13.11.47.

AW.56 Medium bomber to B.35/46 with five engines, 4.47; revised form with four engines late 47

AW.168 Naval strike aircraft to M.148T, 9.54.



Armstrong Whitworth AW.50 (12.42). Note guns mounted between the engines.
Ray Williams Collection



AW.171 Slim delta flying wing aircraft 'A' to ER.161T, 1955. Aerodynamic research aircraft to test flight problems created by very narrow delta or diamond-shaped (lozenge) planforms, for possible long-range bomber or transport. Span 17ft 7in (5.4m), length with probe 75ft 4in (23.0m), wing area (lozenge) 553ft² (51.4m²), leading-edge sweep angle 83°, t/c ratio 6%, two tip-mounted reheated 4,850lb (21.6kN) Bristol Orpheus for forward propulsion, ten vertically mounted 2,100lb (9.3kN) Rolls-Royce RB.108s for VTOL capability, all-up-weight 17,500lb (7,938kg). Pilot in prone position.

AW.172 Slim delta aircraft 'B' to ER.161T, 1955. As per AW.171 but smaller. Span 21ft (6.4m), length 50ft (15.2m), wing area (lozenge) 490ft² (45.6m²), LE sweep 76°, t/c ratio 3%, single fuselage-mounted de Havilland PS.53 Gyron Junior with reheat, no VTOL capability, conventional pilot seat. AWA preferred AW.171 because felt it was more suited than AW.172 for development into larger aircraft.

AVRO / HAWKER SIDDELEY / BRITISH AEROSPACE, MANCHESTER

A bomber specialist, but after the Canberra Replacement programme the factory concentrated on civil aircraft

696 Anti-submarine aircraft to R.5/46. Became Shackleton, first flown 9.3.49.

698 Medium bomber to B.35/46, 5.47. Became Vulcan, first flown 30.8.52. Numerous advanced developments followed.

707 One-third scale 698 to E.15/48 to examine low-speed problems, 1948.

710 Half-scale 698 to test high-speed characteristics, 1948.

716 Shackleton Mk.3 proposal, direct development of the Mk.2, 19.10.50

719 Shackleton Mk.3 proposal, new fuselage and engines on normal outer wings, 1.52.

721 Low-level bomber to B.126T, 12.52.

727 Light ground attack aircraft to NATO requirement, 1954.

730 High-speed high-altitude reconnaissance aircraft to R.156T, 7.55. Construction of modified design with bombing capability begun but cancelled 3.57.

731 Three-eighths scale model test aircraft for 730 to ER.180D, 12.55. Never built.

732 Supersonic bomber powered by four turbojets, 7.56. Information unavailable but believed supersonic variant of Vulcan

738 Designs for a weapon system, 1957. No information available

739 Low-level strike aircraft to GOR.339, 1.58. Design blended with Hawker P.1129 as combined Hawker Siddeley submission against BAC TSR.2, 11.58.

745 Medium-range replacement for Shackleton, 6.58.

752 VTOL assault aircraft, 3.58. No information available

762 Advanced weapons system, 11.58. No information available.

769 VTOL weapons system (Vulcan), early 1960s. No information available

774 Long-endurance weapon system, early 1960s. No information available.

775 Maritime reconnaissance aircraft to replace Shackleton, 1960s. Two RR Tyne plus one rear-mounted RR RB.168.

776 Variant of Type 775 with three RB.178. Span 135ft 8in (41.4m). Length 129ft 4in (39.4m).

784 Maritime reconnaissance aircraft with four turboprop engines, 1960s

HS.801 Anti-submarine aircraft to MR.254, became Nimrod, prototype first flew 23.5.67.

BLACKBURN / HAWKER SIDDELEY / BRITISH AEROSPACE, BROUGH

This company designed new aircraft right through to the 1980s and some of its later projects are still classified, the last design was the P.183. With the total integration of Blackburn into the Hawker Siddeley organisation the B prefix was changed to P, although some brochures actually used an HS prefix, e.g. HS.146.

B.54 Anti-submarine aircraft to GR.17/45. Became Y.A.5, Y.A.7 and Y.A.8. First example flew 20.9.49

B.61 Design study for naval strike aircraft, 1.4.46.

B.66 Transonic four-jet delta wing bomber, 10.9.46. 'Delta' Model 1 (tunnel model?) drawn 26.9.46 had wing fin arrangement quite similar to German Lippisch DM-1 glider of 1944/45. Unknown if B.66 to be similar as design never progressed beyond Project Office. Designer George Petty felt B.66 was good proposal but company lacked resources to follow it through. Delta chosen for aerodynamic reasons but no decision reached to fit or omit tailplane.

Y.B.2 Designation of HP.88 scale model aircraft, 4.48. First flew 21.6.51.

B.79 Anti-submarine aircraft to replace B.54, 26.1.49.

B.83 Light anti-submarine aircraft powered by Rolls-Royce Merlin 35 engine, 24.7.50.

B.88 AEW adaptation of B.54 as Y.B.1, 1950.

B.91 Light anti-submarine aircraft, 1951.

B.96 B.54 with Napier E.141, 1952.

B.103 Naval strike aircraft to M.148T, 9.54. First preliminary drawings 1.12.52. Became Buccaneer S Mk.1 first flown 30.4.58. S Mk.2 developed later with RR Speys.

B.103A RAF version to embryonic GOR.339, 6.57

B.108 Buccaneer development to GOR.339, 1.58.

B.109 Interceptor strike Buccaneer for Canada, 1958. Unsolicited proposal, lengthened nose and tail, non-folding wings, reduced t/c outboard of midwing, twin RR RB.146 engines, 13,000lb (57.8kN) dry, 18,000lb (80kN) with reheat. Span 42ft 6in (13.0m), length 71ft 8in (21.8m), top speed Mach 1.65. No interest in Canada.

B.111 Buccaneer proposal for RAF, 2.60. First Buccaneer with RR Spey (reheated to 18,000lb [80kN]). Various modifications from S Mk.1, take-off weight normal fuel 46,988lb (21,314kg), with tanks 54,200lb (24,585kg). Estimated maximum Mach 0.85 at low level, Mach 1.25 at height (doubted by Air Staff), radius of action normal fuel 840nm (1,557km), with drop tanks 1,000nm (1,853km).

B.113 Variant of B.111 offered to Australia, 5.60.

B.116 Spey-powered Buccaneer offered to West German Navy, 6.60

B.123 Advanced strike aircraft to OR.346, two brochures: 5.7.61 and 9.61.

B.124 Buccaneer development, 1961.

B.126 Land-based Buccaneer development, 1961.

B.127 Variable geometry Buccaneer, 1961.

B.128 Buccaneer Mk.2 with reheated RB.168R Speys for better take-off and manoeuvrability, 1962.

B.130 Advanced strike aircraft, 1962. Details unavailable.

P.131 Subsonic low-level strike aircraft, 1962. Details unavailable.

P.132 Buccaneer S Mk.1 with RATOG, 1962.

P.133 Buccaneer S Mk.2 with RATOG, 1962.

P.134 Buccaneer with improved weapon system, 1962. Became unofficially the Mk 2*.

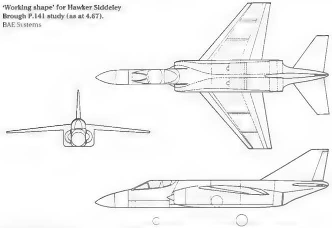
P.135 Variable sweep strike-fighter proposed as Buccaneer successor, 1962. Two reheated Speys, both pivoting and translating wing swing mechanisms investigated for angles between 63° and 25°. Span limits 30ft and 60ft (9.15 and 18.3m), length 59ft (18m), maximum take-off weight 60,000lb (27,216kg). Project to fulfil requirements outlined for B.123; company considered P.135 as far more practical proposition.

P.136 Initial Buccaneer proposals to South Africa, 1962. Became S Mk.50.

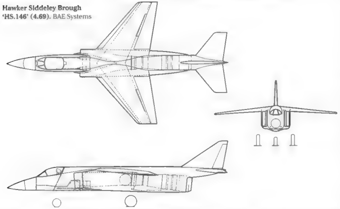
P.138 Counter-insurgency strike fighter, 1962.

P.141 Next Generation Tactical Aircraft, 1964-67. Studied type likely to replace Buccaneer, Phantom and Lightning. Identified need for major advance in aircraft survivability due to

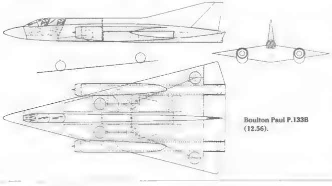
Model of Blackburn B.109 interceptor strike project prepared for Canada (1958).
George Cox Collection



'Working shape' for Hawker Siddeley Brough P.141 study (as at 4.67). BAE Systems



Hawker Siddeley Brough 'HS.146' (4.69). BAE Systems



Boulton Paul P.133B (12.56).

great increase in type's complexity. Fixed and VG investigations but, through drag considerations, main work on compact and efficient fixed sweep layout. With two crew, four 1,000lb (454kg) bombs semi-buried in fuselage and internal fuel for 1,000nm (1,853km) high-level range, minimum take-off weight calculated as 38,000lb (17,239kg). Four wing pylons could take another 12 1,000lb bombs or mix of weapons for ground attack role. Secondary interceptor capability built in with semi-buried Sparrow-type AAMs, also single-seat reconnaissance variant. Production improved by eliminating many small parts and introducing role-related 'building blocks' – alternative noses, single two-seat cockpits and lower front fuselage sections (for sideways-looking radar, Bullpup or Sidewinder missiles) fitted to common core on assembly line. Span 35ft (10.7m), length 56ft (17.1m), wing area 400ft² (41.9m²), two Bristol Siddeley SNECMA M45G turbofans 7,460lb (33.2kN) dry, 13,000lb (57.8kN) reheat, top speed Mach 2, good short-field performance. Considered alternative to MRCA where modular approach reduced size, complexity and cost; company felt the idea of a supersonic strike aircraft compatible with large aircraft carriers was feasible.

P.142 Supersonic Buccaneer, 1965.

P.145 Land-based Buccaneer development, 10.66. Major improvements to standard aircraft plus additional large reconnaissance pack and substantial bomb-carrying capacity. Max. take-off weight 62,000lb (28,123kg). RAF committed to F-111K so did not take up.

P.146 Private venture light ground attack aircraft, 1967-71. First in series of lightweight designs. Utilised Brough's Buccaneer experience in LE and TE flap blowing to give good STOL capability but idea fell away when Harrier VTOL concept was proved. RR Turboméca Adour or RB.199 alternative powerplants. At 4.69 'HS.146' had become carrier-based low-level interceptor and strike type of different configuration for operation with Brough P.139 AEW aircraft. Accent now on manoeuvrability in Mach 0.5 to 1.2 range, simple weapons system with visual acquisition of target after guidance from P.139. Two 30mm guns, two heat-seeking Taildog missiles. Visual strike capability now secondary but delivery of 4,000lb (1,814kg) bombs over 200nm (370km) radius available. One reheated Spey 5R 12,500lb (55.6kN) dry, 21,000lb (93.3kN) reheat (serving with RN Phantoms) or RB.199 14,130lb (62.8kN) dry, 24,700lb (109.8kN) reheat. Span 28ft 6in (8.7m), length 51ft 0in (15.5m), wing area 272ft² (25.3m²), all-up-weight 23,125lb (10,490kg), Mach 1.1 at sea level, Mach 1.8 at 36,000ft (10,973m).

P.148 Retrofit of Spey into Buccaneer S Mk.1, 1967.

P.149 Buccaneer for RAF, 3.69. Development centred on redesigned nav attack system for all-weather capability, bomb bay door with integral fuel tank and RR RB.162 or Rolls Allison XJ.99 take-off boost engine in rear of fuselage. Existing aircraft to be modified. Max all-up-weight (twin 430gal [1,955lit] tanks, six 1,000lb [454kg] bombs) 62,889lb (28,526kg).

P.150 Supersonic Buccaneer for RAF, 1968. Response to Air Staff request for version with reheated Spey 202s. Used variable geometry intakes with translating cones and fitted with thrust reverser. Was 6ft (1.82m) longer than standard aircraft thus eliminating area-rule bulge, had non-folding 6% thick wing, new tail unit and bogie main wheels to deal with extra weight. Maximum speed Mach 1.8, basic weight 7,000lb (3,175kg) above standard S Mk 2.

P.151 Semi-strategic strike aircraft, 1969. Details unavailable but possibly tied in with HS.1179 studies.

P.152 Light tactical aircraft, 1971.

P.153 Lightweight strike fighter, 1969 to 1975. HS.1190 variant to AST 396, 1971.

P.154 Continuation of lightweight studies begun with P.146; Initial Feasibility Study, 9.71.

P.155 Base burning aircraft, 1971.

P.157 Close air support and strike variant of Buccaneer, 5.74. Final proposal for major development of the type; also, as HS.1197, proposed to AST.396.

P.165 Supersonic vectored thrust aircraft, 8.80. Still secret.

P.167 New-generation VSTOL aircraft, 7.81. Still secret.

P.168 Active control technology studies.

P.169 Stealth penetration aircraft. Still secret.

P.170 Light attack aircraft, 11.82. Still secret.

P.177 F-4 Phantom developments.

P.178 Harrier developments.

P.181 ASTOVL developments, 1.87.

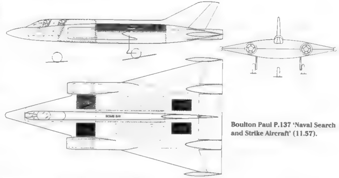
BOULTON PAUL

P.111 Prototype for general delta wing research to E.27/46, first flown 10.10.50.

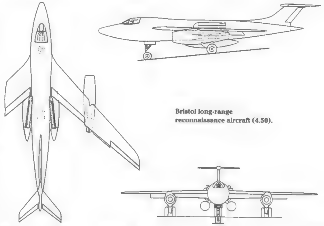
P.120 Delta wing research aircraft developed from P.111, first flown 6.8.52.

P.123 Short-range unmanned expendable bomber to UB.109T, 8.51.

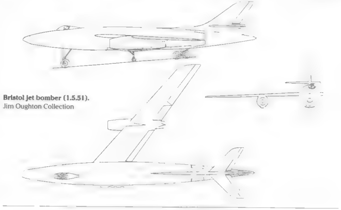
P.133 Dart-shaped fighter and strike aircraft for RAF and Navy evolved from Government-sponsored research on potential use of VTOL fan lift principle. First fighter P.133 (6.56), then smaller P.133A (8.56). Larger P.133B (submitted 12.56), pure naval strike aircraft based on NR.A.39 requirements but designed for catapult launch in zero relative wind conditions. Fan lift system would enable fully loaded aircraft to fly off at 115mph (185km/h). Landing approach speed dependent on weight (at 36,000lb [16,330kg] relative air speed of 63mph [101km/h] required); at lower weights approach speed set by controllability, not by lift (recommended minimum 58mph [93km/h]). Normal all-up-weight 40,120lb (18,198kg) but possible to operate P.133B at 45,000lb (20,412kg) with catapult take-off executed in 28mph (45km/h) relative wind. Two 10,000lb (44.4kN) Gyron Juniors for forward flight. For take-off and landing, jet efflux redirected to two 2-stage turbines with total output of 25,000hp (18,643kW), which drove four 32in (81.3cm) diameter lifting fans. Fan lift forces varied by movable inlet guide vanes and at low forward speeds the normal control surfaces were assisted in pitch and roll by differential thrust from the fans. Total lift force of fans and turbines 34,000lb (151.1kN) and system's centre of lift set behind the CofG to offset the nose-up pitching moment generated by the wing when fans operated in forward flight. Large centreline bomb bay to accommodate two 2,000lb (907kg), four 1,000lb (454kg) or TMB. Span 28ft 0in (8.5m), length 57ft 0in (17.4m), wing area 841ft² (78.2m²), t/c ratio 8%, max. Mach 1.34 at sea level.



Boulton Paul P.137 'Naval Search and Strike Aircraft' (11.57).

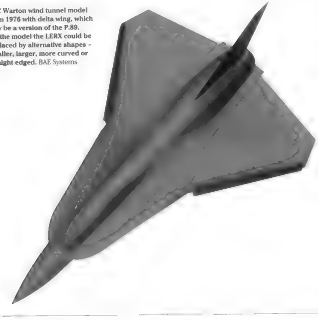


Bristol long-range reconnaissance aircraft (4.50).



Bristol Jet bomber (1.5.51). Jim Oughton Collection

BAC Warton wind tunnel model from 1976 with bombs, drop tanks and Sidewinder AAMs. BAE Systems



BAC Warton wind tunnel model from 1976 with delta wing, which may be a version of the P.89. On the model the LERX could be replaced by alternative shapes – smaller, larger, more curved or straight edged. BAE Systems

P.136 Research aircraft, 8.57. Part of extensive VTOL research programme with P.133, P.135 and P.137.

P.137 Definitive fan lift NR A.39 proposal (though really a research aircraft), 11.57. Layout very similar to P.133B, two mid-span 10,000lb (44.4kN) Gyron Juniors plus ten lift fans converted from RB.108s giving 40,000lb (177.8kN) total thrust in two rows of five each between engines and bomb bay. Ducted-fan system to support 86% of aircraft's weight, fully loaded aircraft to be flown off at 115mph (185km/h). Central bomb bay for same load as P.133B. Span 31ft (9.5m), length 56ft (17.1m), wing area 900ft² (83.7m²), t/c 11%, max. speed 946mph (1,523km/h) at sea level, internal fuel 1,570gal (7,139lit), all-up-weight 46,465lb (21,077kg)

BRISTOL

172 Long-range bomber to unnumbered Air Staff requirement, 5.46 and 10.46.

174 Four-tenths scale model of Type 172 to E.8/47, 2.47.

Reconnaissance Aircraft and Target Marker Small twin-engine recce aircraft for locating and accurate visual marking of target at extreme range, 4.50. High speed over target (582mph [936km/h]) up to 7,000nm (12,964km) away, ceiling 42,000ft (12,802m), gross take-off weight with drop tanks 53,850lb (24,426kg), droppable marking load 1,275lb (578kg), total fuel including drop tanks 31,500lb (14,288kg). One crew aided by automatic navigation, no defensive weapons, new engine required, outer main wheels and RATO units jettisoned after take-off, drop tanks after climb. Span 63ft 0in (19.2m), length 65ft 0in (19.8m), gross wing area 565ft² (52.5m²), t/c 8.5. DMARD (A E Woodward Nutt) noted 'project of great interest technically but Air Staff not interested'.

Jet Bomber Unnumbered design with twin 12,150lb (54.0kN) Olympus Ol.3s, 1.5.51. Long-range recce aircraft (above) had showed some promise so performance of follow-on bomber of similar form now examined. Very high speed (Mach 0.92) and good manoeuvrability at low level in target area, high cruise speed (576mph [926km/h]), height over target with 2,000lb (907kg) load 47,000ft (14,326m) and range 5,600nm (10,371km). Mass balancing effect of wing mounted engines helped avoid flutter during high-speed low-level flight; tunnel test showed good results for close mounted wing nacelles but stalk-mounted alternatives to be assessed. Wing had modified high-lift Fowler flaps between body and nacelles, small span ailerons outside nacelles for rolling power at low level and high speed, large span ailerons extending inwards from tips. All-metal construction, bicycle undercarriage with two-wheel nose, four-wheel main gear and outriggers in nacelles, three crew in nose, provision in tail for one radar guided 30mm cannon. Span 83ft 6in (25.5m), length 100ft (30.5m), wing area 1,000ft² (93m²), t/c 8.0, internal fuel 6,100gal (27,736lit), gross take-off weight 86,600lb (39,282kg), one 10,000lb (4,536kg), one 5,000lb (2,268kg), two 4,000lb (1,814kg) or six 1,000lb (454kg) bombs in bomb bay.

175 Maritime reconnaissance development of Type 175 Britannia airliner, 10.51.

175MR Further maritime reconnaissance development of Type 175 Britannia airliner, 22.4.53

176 Three-tenths scale model of Type 172 to E.8/47 Issue 2, 1.48

182 Short-range unmanned expendable bomber to UB.109T, 9.51

186 Low-level bomber to B.126T, 19.12.52

189 Development of Type 175MR with Nomad engines, c1953.

196 Expendable unmanned bomber variant of Type 188 high-speed research aircraft, 1955. Twin RR Avon or Bristol BE.36 jets.

202 Medium-range low-altitude bomber with twin Olympus, 1957

204 Low-level strike aircraft to GOR.339, 14.1.58

206 NATO Maritime Patrol Aircraft, 5.58.

217 Supersonic strike reconnaissance project, 1959. Single vectored thrust 18,000lb (80kN) Bristol BE.53 and single seat. From the side, it much resembled Hawker Harrier but had tiny wing. Span 13ft 6in (4.1m), length 50ft (15.2m), wing area 107ft² (10.0m²), all-up-weight 13,900lb (6,305kg), top speed 800mph (1,287km/h)

DE HAVILLAND

For a period in the 1950s, there were two de Havilland aircraft design teams: the original Hatfield group and the former Airspeed factory at Christchurch. The latter was mainly responsible for modifying fighters already in production and did not allocate new project numbers, but it did produce two bomber projects.

DH.108 Swallow tailless research aircraft to E.18/45, flown 15.5.46. Based on Vampire fuselage. Designed primarily to probe unknowns of transonic flight for Comet airliner but results benefited aviation in general

DH.110 Christchurch development of fighter as tactical bomber for RAF (26.9.56) and for Navy (23.11.56). Combined for both land or carrier based operation 3.57.

DH.111 Hatfield adaptation of DH.106 Comet airliner to B.35/46, 27.5.48

GOR.339 Unnumbered Christchurch low-level strike aircraft to GOR.339, 23.12.57

DH.127 Hatfield supersonic naval strike fighter and reconnaissance to OR.346, mid-1961

DH.128 Derivative of DH.127.

ENGLISH ELECTRIC / BRITISH AIRCRAFT CORPORATION / BRITISH AEROSPACE, WARTON

This is probably the only project list with new items added in recent years; there are gaps because of security considerations. How far the series has gone is unknown but some of the work will remain secret for many years. Latterly, depth of project investigation has depended on whether the work was undertaken to an MoD order or an internal study only.

A.1 High-altitude bomber project leading to Canberra. Unnumbered proposal with fuselage engines, 1.6.45. First proposal with wing root mounted engines, 7.45, became A.1 on award of contract. First flew (as Canberra) 13.5.49

B.35/46 Unnumbered medium and long-range bomber to B.35/46, 7.4.47

P.2 Intruder variant of Canberra, 18.5.50

P.4 Canberra bomber development with redesigned nose, 2.5.51.

P.10 Supersonic reconnaissance aircraft to R.156T, 30.5.55. Bomber variant considered

P.17 Low-level strike aircraft to GOR.339, 1.58. First studies from mid-1956, blended with Vickers (Supermarine) Type 571 to produce TSR.2, first flew 27.9.64

P.18 Development of Lightning fighter in tactical bombing role, late 1956. Viewed as counterpart to more complex P.17 but unable to meet operational demands. Work ceased 1.57. Single store carried beneath centre fuselage

P.28 Canberra low-level subsonic strike with clipped wings, 1958. Based on B(I) Mk 8 airframe with fighter-type canopy. P.28A span 52ft (15.8m), P.28B 41ft (12.5m), bomb load 10,000lb (4,536kg), 500gal (2,274lit) tip tanks. In April 1965 (same week TSR.2 dropped) BAC produced P.28MOD – major revision of project with Spey engines, TSR.2's forward-looking terrain-following radar and large mix of underwing weapons including anti-shipping and air-to-air missiles. Span 57ft (17.4m), length 72ft (21.9m), maximum take-off weight 60,000lb (27,216kg), bomb load 10,000lb. Both refurbished and new-build aircraft planned

P.31 VTOL strike reconnaissance aircraft to GOR.2, 17.12.59

P.34 Ground attack variant of Lightning for RAF, 7.60. Proposed to convert Mk 1, 2 and 3 aircraft by fitting weapons pack with alternative twin Nord AS.30 missiles, 1,000lb (454kg) bombs, napalm tanks or Zuni rocket launchers

P.37 STOL strike fighter for both RAF and Navy, 1961

P.39 VTOL strike fighter, 19.10.61 onwards. Much of work based on developing an anglicised Dassault Mirage IIIV

P.42 Hypersonic research aircraft, 1962 onwards

P.45 Comparative fixed-wing and variable sweep strike fighter and advanced trainer designs, 19.2.63 onwards

P.46 Jones Committee aircraft studies (many projects, including interceptors), c1964

P.47 STOL Canberra study, 1965/66

AFVG Anglo-French Variable Geometry Aircraft, 5.65 onwards. Joint project between BAC and Dassault of France. Abandoned June 1967

Jaguar Joint project between BAC and Breguet of France, 5.65 onwards. Begun as new pilot trainer for RAF to AST.362, 6.63. As SEPECAT Jaguar first flew 8.9.68

P.49 Light strike trainer with twin podded engines, 12.12.67

P.51 VG strike aircraft, 5.9.67. Became United Kingdom Variable Geometry Aircraft (UKVG), 11.67. Studies continued in 1968 as part of Advanced Combat Aircraft

P.53 Fixed-wing version of UKVG MRCA aircraft, 26.11.68

AA-107 Collaborative venture with Australia for small VG advanced trainer and close support aircraft, 9.68 to mid-1970

P.57 'Package' aeroplane with fixed wing through to VG AA.107 type, 12.6.69

P.60 Proposed family of aircraft – trainer and close support, 1969/70. Includes AA.107

P.61 PANNAP (Panavia New Aircraft Project) family, 1969/70 onwards. Series of trainer, close support and air superiority aircraft from Panavia design team to complement P.60.

P.63 Jaguar developments to AST.396, early studies, 18.3.71.

P.64 New aircraft designs to AST.396, early studies 18.3.71

P.65 GAC/BAC new aircraft (US/UK), 6.10.71

P.66 PANNAP variant, in part to AST.396 Issue 1, 1971

P.67 Panavia MRCA (Tornado) Interdictor Strike IDS variant. Collaborative project between BAC, MBB (West Germany) and Aeritalia (Italy). First flew 14.8.74

P.69 Jaguar developments to AST.396 Issue 1, 24.1.72

P.70 VTOL aircraft to AST.396 Issue 1, 24.5.71. Jaguar and new components, RR Pegasus engine

P.71 Lift + lift cruise variants to AST.396 Issue 1 using Jaguar and new components, 30.9.71.

P.72 Delta and other aircraft studies to AST.396 Issue 1, 1.12.71

P.73 Lightweight VG studies to AST.396 Issue 1, 20.8.72.

P.74 Jaguar developments with new engines to AST.396 Issue 1, 20.3.73

Note: *Project Nos. P.75 and P.80 to P.85 relate to RPV studies*

P.76 MRCA variants to AST.396 Issue 2, 1973. Includes single-seat aircraft

P.77 Minimal change Jaguar variants to AST.396 Issue 2, 13.4.73

P.78 Jaguar variants with new wings to AST.396 Issue 2, 27.6.73. Includes VG wings

P.79 Jaguar variants with new fuselage and existing wings to AST.396 Issue 2, 6.12.73

P.86 Long-term Jaguar developments to AST.396 Issue 3 and AST.403, 1975

P.87 Jaguar short and medium-term developments, 4.8.75

P.88 Blended body fixed-wing aircraft, 30.10.75.

P.89 Blended body delta-wing aircraft, 26.1.76.

P.90 Non-blended VG aircraft, 21.10.75

P.98 Delta wing aircraft, 1.8.77

P.100 RR Pegasus-powered tilt-wing aircraft.

P.101 Blitz fighter gunship Strikemaster development, 3.7.78

P.102 Tilt-wing vectored thrust aircraft, 25.2.80

FOA Studies for a Future Offensive Aircraft to replace Tornado, 1994/95 onwards. Soon afterwards was redesignated Future Offensive Air System (FOAS).

FAIREY

Fairey did not make full use of project numbers. Consequently, this list comprises those bomber related projects known to have been undertaken.

Gannet Various studies for anti-submarine aircraft to GR.17/45. First brochure 14.12.45. As Type Q became Gannet, first flew 19.9.49

Project 45 Cut-down version of GR.17/45 as light A/S aircraft with single Mamba replacing Double Mamba power unit, 12.10.51. Fuselage structure forward of front spar frame redesigned, ASV.19 scanner relocated to front end of bomb bay. Lightest version all-up-weight 14,500lb (6,577kg), top speed 241mph (388km/h) at 5,000ft (1,524m). Span 54ft 4in (16.6m), length 42ft (12.8m), wing area 471.5ft² (43.8m²)

M.148 Naval strike aircraft to M.148T, 9.54

'Delta III' Fighter-bomber variant of all-weather fighter to F.155T, 1.57. Powerful engines coupled with delta wing gave flexible aircraft well suited to offensive and recce roles. Interceptor's Rolls RB.128 engines replaced by Bristol Olympus 21Rs for better low-altitude fuel consumption (engine still well suited for medium-altitude interception), massive ventral drop tank for much-improved range, radar replaced by low-altitude bomb sight. Two underwing pylons for TMB, armour-piercing bombs or RPs. For supersonic flight weapons held in special underwing containers cooled by air from aircraft's system to reduce

temperature effects (prolonged supersonic flight would normally take temperature above point at which spontaneous explosion occurs) With TMB and fuel for 630nm (1,167km) sea level radius of action, all-up-weight 73,100lb (33,158kg) Fairey felt that with suitable AAMs the aircraft could still intercept bombers at medium altitude which, with Mach 2 capability, made this 'one of the most powerful fighter-bombers ever conceived'.

GOR.339 Low-level strike aircraft to GOR.339, 1.58.

NATO Maritime Patrol Aircraft Project to NATO requirement, 21.6.58.

FOLLAND

(See HS.1170 and HS.1171 for additional projects)

Gnat Light ground attack variant of fighter to NATO requirement, 1954.

Fo.147 Twin-engined VG aircraft as basis for strike trainer, 4.61.

Fo.148 Advanced supersonic weapons and operations trainer and strike/recce aircraft with single RB.153-61R, late 1961 onwards.

GLOSTER

A fighter specialist that just occasionally dealt with bombers. The P numbers list drawings, not projects.

P.109 First 'Gloster Jet Bomber' proposal with four Whittle W2B jets in individual pods, 12.8.41 (drawing number unknown) Modified P.109 proposed 24.11.41 with engines podded in pairs. Not intended as formal project, rather first examination of how the new jet engine could be used in a bomber. Span 100ft (30.5m), length 72ft (21.9m), gross weight 36,000lb (16,330kg), speed over target 405mph (652km/h) at 40,000ft (12,192m).

P.303/ G.44 Ground attack variant of Meteor F Mk.8 with four 1,000lb (454kg) bombs, 2.50. Flown as private venture 4.9.50. Unofficially called Reaper; P.304 carried RPs, P.306 had long-span wings

P.317 Long-range fighter-bomber development of F.4/48 (Javelin), 5.50. Four 1,000lb (454kg) bombs in two streamlined ventral panniers, one each side of aircraft's centreline.

P.324 Long-range fighter-bomber version of P.322 F.4/48 interceptor variant, 7.50.

P.384 Development of Thin Wing Javelin fighter to GOR.339, 11.57. Podded engines.

P.386 Development of Thin Wing Javelin to GOR.339, 11.57. Engines in fuselage.

HANDLEY PAGE

A company that, from a warplane point of view, concentrated entirely on bombers.

HP.80 Medium bomber to B.35/46, 5.47. Became Victor, first flown 24.12.52.

HP.87 One-third scale model glider of HP.80, 1947.

HP.88 Four-ninths scale HP.80 wing and tail on fuselage of Supermarine Attacker fighter to E.6/48, 4.48. Also called Supermarine Type 521 and, by Blackburn who built it, YB.2. First flew 21.6.51.

HP.98 Target marker variant of HP.80, four RR Conway engines, 11.51

HP.99 Low-level bomber 'Daisy Cutter' to B.126T, 1.53.

HP.100 High-speed high-altitude reconnaissance aircraft to R.156T, 5.55. Designed to also carry ballistic missiles.

- Victor Phase 2, spring 1955.

HP.104 Victor Phase 3 with four Bristol Olympus Ol.7s, 28.4.55

HP.106 Cruise missile to OR.1149, 24.11.55 HP.106M of 8.57 had eight RB.93/4 jets with reheat, Mach 3.0 speed and 1,200nm (2,224km) range.

HP.107 Supersonic bomber project, five Olympus engines, 24.11.55 Believed to have 60° delta wing, engines either in rear fuselage or under wing. Uncertainty surrounding position of horizontal stabilising surfaces – switched to 'canard' and back several times as difficulties arose with HP.107's balance. Believed that conventional rear surface was final choice.

- Victor Phase 4 supersonic development, 10.56.

GOR.339 Outline study only for tactical strike aircraft to GOR.339, 1.58.

HP.114 Victor Phase 6 missile carrier, 14.8.58.

OR.354 Firm completed brief study 12.61 for TSR.2 replacement.

HAWKER / HAWKER SIDDELEY / BRITISH AEROSPACE, KINGSTON

One of the most famous of fighter manufacturers which rarely forayed into bomber development until the lead-up to the 'Canberra Replacement'. However, once the vertical take-off P.1127 and Harrier were flying, much of Kingston's effort centred on advanced versions which predominantly fit into the attack aircraft category. The prefix reverted to 'P' after the formation of British Aerospace in 1977.

P.1041 Mosquito replacement, 1944/45.

P.1044 Naval fighter-bomber, 1945

P.1051 Naval medium bomber, 8.4.46. Twin RR AJ.65 (Avon), span 58ft 0in (17.7m), length 58ft 0in (17.7m), gross wing area including intakes 660ft² (61.4m²), 800gal (3,638lit) fuel all in fuselage, bomb bay for large missile.

P.1099 Hunter F Mk.6 fighter – later developed into successful ground attack FGA Mk.9. First conversion flew 3.7.59 Could carry Nord AS.30 or Bullpup missiles, RPs and 1,000lb (454kg) bombs.

P.1108 Naval strike aircraft to M.148T, 30.9.54.

P.1121 Version of strike fighter offered as tactical bomber for RAF, 10.3.57. Final proposal for two-seat all-weather strike reconnaissance variant 1.7.58.

P.1123 Enlarged two-seat P.1121 as Mach 2 tactical bomber, 21.1.57.

P.1125 Supersonic strike aircraft project for RAF, 3.57

P.1126 VTO double-delta strike aircraft with 12 RR RB.108 lift jets and twin Bristol Siddeley propulsion units, 6.57

P.1127 Vertical take-off research aircraft to ER.204D, first flown 13.3.61 Developed into Kestrel and Harrier close support aircraft.

P.1129 Low-level strike aircraft to GOR.339, 1.58 Design blended with Avro 739 as combined Hawker Siddeley submission against BAC TSR.2, 11.58

P.1132 Subsonic VTOL strike aircraft, 4.58.

P.1134 Mach 3 to Mach 4 research aircraft, 1958 onwards

P.1136 Canard VSTOL aircraft, four RB.108 lift units, one reheated cruise engine, 4.59

P.1137 Straight-wing supersonic tactical VSTOL aircraft, alternative to subsonic P.1127, 7.59. Seven RR RB.153 lift engines, three for lift in forward fuselage, two lift-cruise units with diverters and reheat in rear fuselage, one each with reheat in tilting wing tip pods RB.153 was latest lightweight lift and propulsion engine but mass of power units gave high wing loading (feature common to most VTOL designs) and study concluded that supersonic capability 'would nearly double the take-off mass of V/STOL tactical aircraft' (a long-term problem) Span 32ft 2in (9.8m), length 53ft (16.2m), gross wing area 250ft² (23.25m²), internal fuel 1,100gal (5,002lit).

P.1138 VTOL naval aircraft with canard and RB.153 lift and lift/cruise engine, 1959.

P.1139 Subsonic V/STOL strike fighter, 17.2.60. Two RB.153 lift units in forward fuselage, one reheated RB.163-1 clang-box lift/cruise unit in mid-fuselage with tail jet pipe plus diverter in bottom fuselage just beyond wing trailing edge Span 25ft (7.6m), length 50ft 6in (15.4m), wing area 219ft² (20.4m²), internal fuel 600gal (2,728lit), wing t/c 7% For hover thrust the diverter deflected gases away from tail pipe down through bottom fuselage exit, thus balancing the forward vertically mounted engines.

P.1140 Supersonic V/STOL strike fighter similar to and developed from P.1139, 4/3.60 Larger aircraft with three RB.153 lift units in forward fuselage, reheated RB.163-1 clang-box cruise engine had supersonic intakes Span 26ft (7.9m), length 57ft 7in (17.6m), wing area 25ft² (20.9ft²), internal fuel 700gal (3,183lit), wing t/c 5%.

P.1141 Supersonic V/STOL strike fighter, 5.60. Single reheated BE.53/11, forward pair of thrust vectoring nozzles plus tail jet pipe, span 25ft (7.6m), length 49ft (14.9m). Second version had VG wing

P.1143 Large supersonic strike fighter, ten RB.153s, 7.60 Long slim fuselage with six vertical RB.153s for lift only (three between cockpit and wing, three alongside wing trailing edge) and two pairs in swivelling wing tip nozzles (one above the other) for propulsion and VTOL lift Straight-wing leading edge, trailing edge swept forward as per P.1137

P.1144 Supersonic V/STOL strike fighter, 10.60 Multi-engined using RB.163 with PCB. Gross weight 30,000 to 40,000lb (13,608 to 18,144kg).

P.1146 Supersonic V/STOL aircraft, 1960.

P.1149 Supersonic V/STOL strike aircraft, 2.61. Twin reheated RB.168R Spey for cruise, six RB.162 lift engines in two banks of three (one set forward, the other to rear) with both sets placed between main engines and exhaust pipes Each RB.168 had single vectoring nozzle directly beneath VG wing for extra lift in hover. Two seats, span spread 47ft (14.3m), span swept 26ft (7.9m), length 62ft (18.9m), wing area spread 442ft² (41.1m²) swept 390ft² (36.3m²)

P.1150 Supersonic V/STOL strike fighter, 1.61 onwards Developed into P.1154

P.1151 Supersonic jet flap strike aircraft to OR.346, 4.61

P.1152 Supersonic RAF/Naval V/STOL strike fighter to OR.346, mid-1961

P.1153 Supersonic strike aircraft to OR.346, 4.61.

P.1154 (Originally P.1150/3) Supersonic V/STOL ground attack fighter with BS.100 PCB vectored thrust turbofan to NATO requirement NBMR.3, and AW.406 OR.356, 10.61 onwards. Prototype construction begun, but project cancelled 2.65.

P.1155 (Originally P.1150/2) Supersonic V/STOL strike aircraft to NBMR.3, 4.62. Alternative to P.1154

P.1156 V/STOL strike aircraft, 12.61.

P.1158 Supersonic V/STOL aircraft derived from P.1155 with two Bristol Siddeley Pegasus 6 and PCB, 1962.

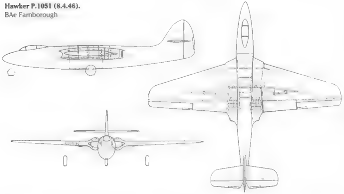
P.1159 V/STOL aircraft designed as replacement for Fiat G.91 with BS.94/4 and twin RB.162s, 1963.

P.1163 Fiat G.91 replacement with RB.168 and PCB, 1963.

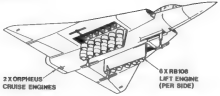
Note: *Project Nos. P.1161, P.1162 and P.1164 to P.1169 not allocated*

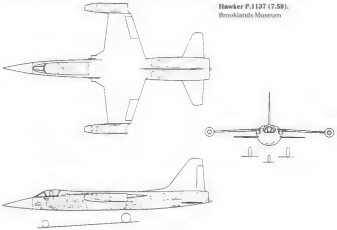
HS.1170 Lightweight V/STOL strike reconnaissance aircraft developed from P.1163 to NATO VAK.191 competition ('191' indicated G.91 successor) with BS.94/5 PCB vectored thrust engine, 1964 Joint project with Focke-Wulf. Small aircraft with appearance similar to early Kestrel but rear fuselage considerably

Hawker P.1051 (8.4.46).
BAe Farnborough



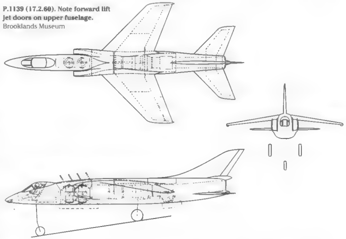
Impression of Hawker P.1126.

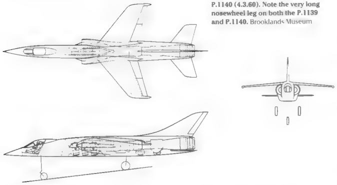




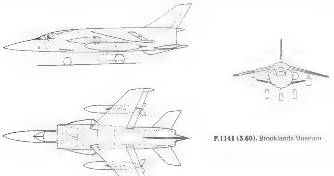
Hawker P.1137 (7.59).
Brooklands Museum

P.1139 (17.2.60). Note forward lift jet doors on upper fuselage.
Brooklands Museum

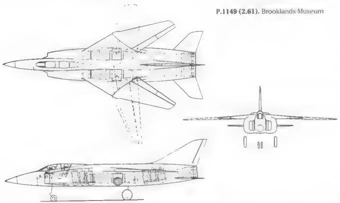




P.1140 (4.3.60). Note the very long nosewheel leg on both the P.1139 and P.1140. Brooklands Museum



P.1141 (5.60). Brooklands Museum



P.1149 (2.61). Brooklands Museum

slimmer Span 18ft (5 5m), length 38ft (11 6m) Also HS.1170B Folland Hamble strike trainer variant to AST 362, 5 64

HS.1171 Folland Hamble VG aircraft with twin RB.172 engines to AST.362, 5 64.

HS.1173 Light advanced trainer to AST.362, twin RB.172s, 1964 65 Single-seat single reheated engine ground attack variant also drawn.

HS.1175 Second-generation subsonic V STOL strike aircraft, 1966 onwards.

HS.1176 Subsonic V STOL strike aircraft proposed to United States, late 1966 onwards Externally similar to Harrier

HS.1177 Supersonic V STOL strike and recce aircraft, 1966 onwards First variant (28 7.67) had single reheated BS.53 103 Pegasus cruise lift engine plus one RR Allison XJ-99-RA-1 lift unit, second (5.8 67) had twin reheated RR Spey 5Rs and an XJ-99-RA-1, third (18.8.67) had twin RB 168-31Ds only

HS.1178 Subsonic V STOL strike aircraft with PCB Pegasus, 1967.

HS.1179 Supersonic strike aircraft studies to MRCA standards, mid-1968 to 2 70

HS.1180 RR Spey-powered version of P.1154, 1965-68

HS.1181 V STOL wide speed range aircraft with BS Pegasus 9D and 'pop-out' RR RB.202-10 lift fans, 1968. Appearance similar to Harrier family.

HS.1184 Long series of subsonic Harrier developments, 7.70 through 1974 Both HS.1184 and HS 1185 popularly known as Super Harrier

HS.1185 & AV-16 Subsonic and supersonic V STOL strike aircraft, 1970 to 1975. Anglo US study from 1973 planned for service use as AV-16; cancelled 1975.

HS.1186 Advanced Harrier with Pegasus 16C, 9.71. Six underwing hardpoints, one under fuselage, span 34ft (10.4m), length 52ft (15.8m), wing area 330ft (30 7m)

HS.1187 Supersonic V STOL strike fighter with PCB Pegasus 16C, 1970. Exhausts pushed below level of lower fuselage; variant had cranked delta wing and twin fins

HS.1188 HSA/McDonnell Douglas advanced Harrier with Pegasus 16, 1970 71.

HS.1189 Kingston Brough simple strike aircraft to AST.396 Issue 1, 1971 72.

HS.1190 Kingston Brough (P 153) light strike to AST.396 Issues 1 and 2, 1971 73.

HS.1191 Kingston Brough (P.155?) base-burning aircraft, 1971 Single RB.199R with, or without, XJ-99 type lift engines.

HS.1192 Large Kingston Brough supersonic V STOL strike type, AST.396 Issue 1, 1972

HS.1193 Supersonic V STOL with PCB Pegasus 15 and nawar delta wing, 29.6.73.

HS.1194 Lightweight supersonic STOL with RB.199, 1972 73.

HS.1195 STOL strike aircraft with RR Spey developments, 1973 74. Several designs, one to AST.396 Issue 2.

HS.1196 MINICAS very small close air support type, 1973 74 Submerged cockpit, engine in pod on back of fuselage, various engines including RB.401, weapons included anti-tank missiles.

HS.1197 Buccaneer development to AST.396 Issue 2, 1974.

HS.1198 Variable cycle vectored thrust research aircraft, single RR RB.406, 13 1 75. Span 28ft (8.5m), length 53ft (16.2m), wing area 250ft (23.3m²). Also version with side intakes.

Big Wing Harrier Study to fit big wing to Harrier aircraft as GR Mk.5, 1976 to 1978. Replaced by HSA McD AV-8B; prototype first flew 9.11 78

P.1208 Ground attack type with air combat capability, 5 78 onwards. P 1208-1: side intakes and conventional swept wing; P.1208-2 (15 9 78): chin intake, canard and forward sweep

P.1209 Supersonic VSTOL demonstration aircraft, test bed for PCB Pegasus, 1978 79. P.1209-2 dated 5.1 79

P.1213 V STOL canard design with Pegasus engine, 1979.

P.1218 F-14 Tomcat A-6 Intruder replacement for USN, 1981

P.1222 V STOL with RR Bristol tandem fan engine, 1983.

P.1226 Initially subsonic variant of P 1216 fighter layout, 1984 Later P.1226-2 (1 8 84) essentially forward sweep version of Harrier II

P.1228 Supersonic naval V STOL with PCB and canard, 1985. Strike and interceptor capability.

P.1229 Supersonic naval V STOL with dry engine, P.1184 configuration, 1985.

P.1230 Supersonic naval V STOL with PCB, P.1205 configuration, 1985.

P.1231 Supersonic V STOL with four-nozzle engine, AV-16-S4 revived, 1985.

P.1232 Sea Harrier FRS Mk.2 front fuselage with 8in (20.3cm) plug, Sea Harrier wing, Harrier GR Mk.5 rear fuselage, 10 9 85.

P.1233 Small Agile Battlefield Aircraft (SABA), 1987

P.1234 Three layouts for SABA, 1987.

P.1236 SABA studies not in final brochure

P.1237 ASTOVL aircraft with advanced RALS (Remote Augmentation Lift System) powerplant, 1986

P.1238 Simple 'low technology' SABA, 1987.

PERCIVAL

Renamed Hunting Percival Aircraft in 1954, the company became part of BAC in 1960.

P.61 Swept-back research aircraft, c1948.

P.70 Naval anti-submarine aircraft, c1949.

P.97 Naval strike aircraft (possibly to M.148T, 1954).

H.128 Single-seat ground attack aircraft utilising Jet Provost trainer's wings, rear fuselage and empennage, RB.145 engine.

BAC.167 Strikemaster ground attack variant of Jet Provost T Mk 5 trainer developed specifically for small overseas air forces. Uprated RR Viper engine and increased weapon capability First example flew 26.10.67, type proved very successful.

H.168 Ground attack derivative of Jet Provost with larger military load over greater distance RB.172 T.260 engine.

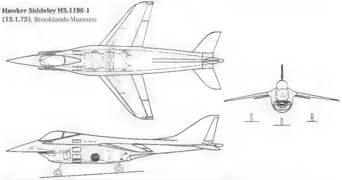
H.171 Ground attack Jet Provost with RB.153-61.

SAUNDERS-ROE

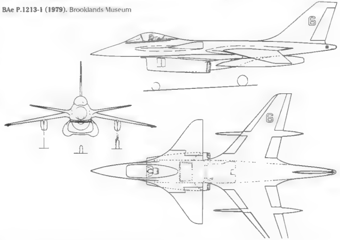
Saro had long experience designing flying boats but in the 1950s it also produced the occasional bomber project.

P.178 Swept-wing naval strike aircraft designs, 1.54 and 4 54

P.188 Schemes for high-speed high-altitude reconnaissance aircraft to R.156T, 7.55. Not known if designs adapted to carry bombs. No official tender to specification.



Hawker Siddeley HS.1198-1 (13.1.75). Brooklands Museum



BAe P.1213-1 (1979). Brooklands Museum

SHORT BROTHERS & HARLAND

This company's main number sequence, the S series, embraced projects from Rochester and Belfast over many years. The P D. series applied to Belfast preliminary designs originating from 1947 onwards as schemes or tenders. If the latter progressed beyond this stage, a number was allocated in the SBAC designation system

S.42 / S.A.4 Sperrin First S A.4 six-engine bomber, 11 45, followed by similar four-engine design 26 4.46. Developed into Sperrin first flown 10 8.51.

S.B.1 (P.D.1) Medium bomber to B.35 46, 5.47. One-third scale glider also called S.B 1 built to test aero-isoclinic wing. First flew 14.7.51.

S.B.3 Anti-submarine development of Sturgeon naval aircraft to M.6 49. Prototype first flew 12 8.50

S.B.4 Rebuild of S B 1 glider with Blackburn-Turboméca Palas jets. First flew 4.10.53. Named Sherpa.

S.B.6 (P.D.4) Seamew Anti-submarine aircraft to M.123D. First flew 23.8.53

S.C.1 VTOL research aircraft to ER.143T. First flew 2.4.57

S.C.2 Proposed Seamew Mk.2 for Coastal Command

P.D.6 S.A.4 Sperrin test bed for DH Gyron engine. First flew 7.7 55

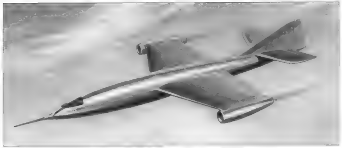
P.D.9 Low-level bomber to B 126T, 12.52.

P.D.12 High-speed high-altitude reconnaissance aircraft to R 156T, 5.55

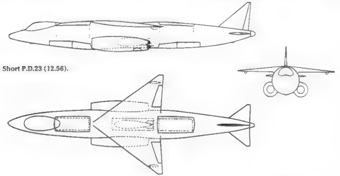
P.D.13 Naval strike aircraft to M 148T, 9.54.

P.D.17 Projects to GOR.339 with English Electric, 1957 58. Included lifting body.

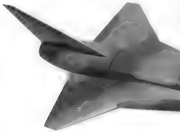
P.D.23 Four schemes for VTOL naval strike aircraft, 12.56. During late 1950s Shorts undertook much research into VTOL using any number of lift engines. P.D.23 was a large project but example shown had small wing. Two crew, span 28ft 0in (8 5m), length 72ft 6in (22.1m), wing area 300ft² (27 9m²), t c 6%, operating weight 36,955lb (16,763kg), gross weight 62,000lb (28,123kg), maximum wing loading 207lb ft (1,011kg m), fuel 2,783gal (12,652lit), large bomb. Two Avon RA 29 propulsive



Artist's impressions of two unnumbered Shorts bomber projects (10.53 and 11.53). No details are available. Both Shorts



Short P.D.23 (12.56).



A view of the Short P.D.49 model in early form with double-delta wing (11.60). The black-lined box over the upper fuselage presumably indicates the lift engine position. Shorts

engines, twenty RB.108 lift units in two banks in front of and behind wing. Maximum Mach 1.0, cruise Mach 0.9, range 450 miles (724km).

P.D.25 Five schemes for VTOL ground attack aircraft, late 1950s into 1960. Delta wing, delta canard on nose, propulsive engines in (swivelling?) wing tip pods, lift engines in fuselage behind cockpit.

P.D.33 Proposal for Canberra with increased span.

P.D.44 Naval strike aircraft, 1960-61.

P.D.45 VTOL low-level strike aircraft, 1960-61.

P.D.49 VTOL light strike reconnaissance to NATO limits (250nm [463km] sea level range with 2,000lb [907kg] load), 1960-61. First studies (9.60) show double delta; by 6.61 had pure delta with eight RB.162 lift units (two groups of four in centre fuselage) and one propulsive reheated RB.168-1R. Maximum Mach 1.73 at 36,000ft (10,973m) at 26,000lb (11,794kg) weight but airframe could go faster with more power. Lift engines close to CofG to minimise offset moment resulting from a failure during jetborne flight – effect of failure counteracted by nozzle control system. Central lift engines meant propulsion installation in rear fuselage, longitudinal balance achieved by placing all equipment in forward fuselage forward and aft of cockpit. Lower ends of lift engines tilted outwards to allow semi-submerged bomb stowage on centreline (one tactical nuclear or 1,000lb [454kg]) with minimum additional drag. Lift nozzles tiltable so horizontal component of lift thrust could be generated for acceleration or deceleration in transitional flight. Main engine fed by air passing either side of lift units joining up in front of main engine – duct walls integrated with fuselage structure to save weight. For jetborne control, hovering control system similar to S.C.1's. Weapons include Bullpup or Nord AA.20 missiles, RP packs, 1,000lb bombs or Firestreak AAMs on four underwing pylons, twin 30mm Aden cannon and retractable 2in (5.1cm) air-to-air RP launcher in bay forward of lift units between main intake ducts. Span 28ft (8.5m), length 53ft 6in (16.3m), VTO weight 23,000lb (10,433kg). Provision for Ferranti Airpass IIC multi-purpose radar. Alternative design had twin RR RB.179 main units.

P.D.56 VTOL strike fighter to NBMR.3, 1961-62.

P.D.69 Anti-submarine aircraft to AST.357, c1963.

VICKERS-ARMSTRONG

After 1960, Weybridge combat aircraft projects were listed as a continuation of the old Supermarine list (below).

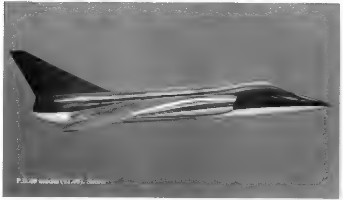
Jet Bomber High-altitude bomber, 3.45. Four 8,000lb (35.6kN) RR jets stacked in pairs forward of wing, air fed from nose intake, individual very long jet pipes (would have been two-thirds shorter if discharged through fuselage sides just aft of wing, but rejected by structural problem of holes in side and thrust loss when turned 7° to side, 10° down). Engine nacelles rejected through drag and effects on laminar flow. Three crew in nose, tricycle undercarriage with six-wheel nose and four six-wheel main units. Sideways wheel retraction rejected through difficulty providing sufficient torsional stiffness in wing – chassis nacelles estimated to increase thrust required for specified cruise by 6% only and shaped such that laminar flow preserved along whole span. Recovery dive flaps fitted, landing flaps omitted, structure metal covered throughout bar control surfaces. Stowage for two 22,450lb (10,183kg) 'Grand Slam', four 13,000lb (5,897kg) 'Tallboy' or combinations of smaller, no defensive weapons since thought difficult to intercept at planned speed and height. Max. bomb load 52,000lb (23,587kg), normal 24,000lb (10,886kg), normal all-up-weight 102,000lb (46,267kg), overload 120,000lb (54,432kg). 4,000gal (18,188lit) internal fuel. Cruise 475mph (764km/h) at 45,000ft (13,716m) and 102,000lb weight, top 530+mph (853+km/h) in light condition above 35,000ft (10,668m), sea level climb 3,400ft/min (1,036m/min), range 1,250 miles (2,011km) at overload, 2,000 miles (3,218km) at normal load. Span 169 ft (51.5m), length 122ft (37.2m), wing area 2,860ft² (266m²), t/c 15%.

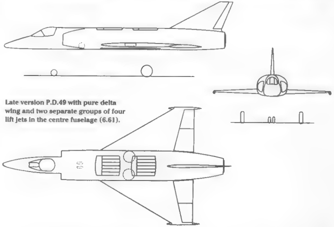
B.35/46 Medium bomber project to specification, 5.47. Revised version 3.11.47.

660 Medium bomber to B.9/48. Covers first prototype WB210, first flew 18.5.51.

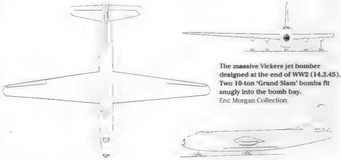
Long-Range Bomber Three schemes based on Valiant 8.49, updating initial work of 5.49. Scheme 1 basis was development of B.9/48 but with 45° continuous sweep instead of 'crank' plan form, longer fuselage, bicycle undercarriage (thin wing could not house conventional gear) and five 9,700lb (43.1kN) RB.80/1s – four in wing roots, one in fuselage tail. Was described by Vickers as 'fairly representative of the British approach' and cruised over target at 576mph (926km/h) and 49,000ft (14,935m). Span 128ft 0in (39.0m), length 134ft 8in (41.0m), gross wing area 3,200ft² (297.6m²), t/c ratio root 12%, tip 8%, total take-off weight 163,600lb (74,209kg), full load service ceiling 49,800ft (15,179m). Max speed at mean weight of 123,560lb (56,047kg) 618mph (995km/h) at sea level, 629mph (1,012km/h) at 30,000ft (9,144m); full load rate of climb 4,680ft/min (1,426m/min) at sea level, 2,450ft/min (747m/min) at 30,000ft.

After examining American practice Vickers felt it would be worthwhile to do alternatives based on American concept of higher wing loads and aspect ratios. Scheme 1 aspect ratio 5.12 and take-off wing loading 51.1lb/ft² (249.5kg/m²); Schemes 2 and 3 loadings and aspect ratios progressively higher and both had engines in external nacelles because insufficient depth to fit them in wing. Aspect ratio of 2 and 3 = 6.82 and 8.58 respectively, wing area 2,405ft² and 1,910ft² (223.7m² and 177.6m²), total take-off weight 165,500lb and 167,150lb (75,071kg and 75,819kg), take-off wing loading 68.8 and 87.5lb/ft² (335.9 and 427.2kg/m²), over target cruise 567mph (912km/h) at 49,800ft (15,179m) and 580mph (934km/h) at 50,000ft (15,240m), full load service ceiling 48,800ft (14,874m) and 49,000ft (14,935m) respectively. Scheme 2 used 10,000lb (44.4kN) of rocket thrust to get off at full load, Scheme 3 needed 20,000lb (88.9kN). Scheme 2 span 128ft 0in (39.0m), length 116ft 0in (35.4m), t/c ratio 12% to 10%, max speed at a mean weight of 121,350lb (55,044kg) 623mph (1,002km/h) at sea level, 628mph (1,010km/h) at 30,000ft, full load rate of climb 4,670ft/min (1,423m/min) at sea level, 2,400ft/min (732m/min) at 30,000ft. Scheme 3 span 128ft 0in, length 109ft 6in





Late version P.D.49 with pure delta wing and two separate groups of four lift jets in the centre fuselage (6.61).



The massive Vickers jet bomber designed at the end of WW2 (14.3.45). Two 10-ton 'Grand Slam' bombs fit snugly into the bomb bay. Eric Morgan Collection

(33.4m), t c ratio 12% to 10%, maximum speed at mean weight of 123,860lb (56,183kg) 654mph (1,053km h) at sea level, 632mph (1,017km h) at 30,000ft, full load rate of climb 5,000ft min (1,524m min) at sea level, 2,580ft min (786m min) at 30,000ft All achieved 5,000nm (9,265km) range with 10 000lb (4 536kg) bomb: load included one 10,000lb 'special' or HC two 5,000lb (2,268kg) HC or 15 1,000lb (454kg) MC Concluded that RATOG essential for Schemes 2 and 3 and both showed high take-off and landing speeds, poor margin of excess 'g' for manoeuvre and increase in profile drag of about 15% Scheme 1 was 'best solution', bearing in mind British aerodrome limits and that design could manoeuvre at minimum of 2'g'

667 Second Valiant prototype WB215 (Sapphires instead of Avons)

673 Valiant B Mk.2 prototype WJ954, first flew 4 9 53. Unofficially called Pathfinder.

674 Early production Valiant B Mk.1.

706 Main production Valiant B Mk.1.

710 Valiant B(PR) Mk 1 production

711 First studies for Red Rapier flying bomb, 1951

712 Proposed conversion of Valiant B Mk 2 with RR Conway engines, 1951

718 Proposal for Valiant Pathfinder with Conway engines, 1951

– Combined brochure for separate low-level and supersonic Valiant developments, 1 52

719 One-third scale model of Red Rapier flying bomb, 1951

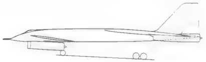
722 Proposed Valiant Mk.3, 5.52

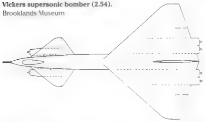
725 Red Rapier flying bomb to UB 109T, 9.51

– Supersonic bomber, 2.54 Preliminary investigation into suitable aircraft for high-altitude long-range supersonic bomber role To carry 5 000lb (2,268kg) bombs internally for still air range of 4,315nm (7,991km) with over target height of 70,000ft (21,336m), cruise at Mach 2.2 to 2.5 throughout flight Used all-moving foreplane and light alloy construction (Hiduminium RR 58 suitable for use up to 190°C, the temperature experienced at Mach 2 5) and six non-reheated Rolls-Royce turbojets designed specifically for supersonic cruise (current engines unsuited to long-range cruise between Mach 1 5 and 3 0) High power and low landing wing loading enabled flaps to be dispensed with. Used single crewman Top speed Mach 0.53 404mph (650km h) at sea level, Mach 1 12 740mph (1 191km h) at 36,000ft (10,973m), Mach 2 5 1,651mph (2,656km h) at 70,000ft Span 60ft 10in (18.5m) length 101ft 6in (30 9m) gross wing area 1 850ft (172 1m²), t c ratio 3.5%, foreplane span 25ft 10in (7 9m), area 416ft (38.7m), all-up-weight 175,000lb (79,380kg)

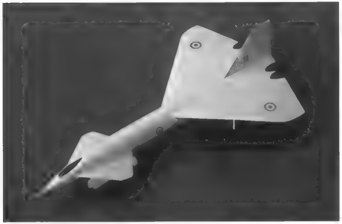
799 High-speed high-altitude reconnaissance aircraft to R.156T, 5 55

Swallow Studies from 1954 by Barnes Wallis into arrow wing VG aircraft Military proposals based on requirements of R.156T (10 55) and OR.339 (4.58)





Vickers supersonic bomber (2.54). Brooklands Museum



Model by John Hall of the Vickers supersonic bomber.

VICKERS SUPERMARINE

Accurate dates for many of these projects are unavailable since brochures were often undated Designs from 1960 onwards originate from the Vickers BAC Weybridge team who used the old Supermarine project number series

521 Designation for HP.88, 4.48.

522 Conversion of Type 508 N 9 47 fighter into strike aircraft to NR A 19, 10 48.

537 Strike conversion of Type 525 N 9 47 fighter to NR A 19, 4 50

544 Scimitar jet fighter to N 113D, first flew 19.1 56. In FAA service role switched to strike prior to introduction of Buccaneer

561 Scimitar low-level nuclear bomber development for RAF, 1956

562 Interceptor and strike development of Scimitar, 1.56 to 3 57.

564 Revision of Type 562 as naval strike aircraft, 1956 57

565 Scimitar tactical bomber development for RAF, 2 57

566 Scimitar strike variant for Navy, Sperry Integrated Flight Control System, 2.57.

567 Scimitar single and two-seat strike developments for Navy, 4.57.

569 Guided powered bomb for carriage by V-bombers 1957. Powered by four RR RB 93 4 Soar motors

571 Low-level strike aircraft to GOR.339, 1 58 Result of studies undertaken during 1957 Blended with English Electric P 17 as TSR.2, first flew 27 9 64.

572 Denavalised tactical reconnaissance Scimitar for RAF, 1958

574 Scimitar project, 1958

576 Supersonic Scimitar developments, 12.58 onwards

577 Various projects for supersonic strike aircraft, 1959 60 Early study (26.6.59) showed high delta wing and all-moving low-set tail Twin BE.61 ducted-fan engines, wing area 410ft (38.1m), fuel 1,800gal (8,184lit) in fuselage, 180gal (818lit) in wings, 400gal (1,819lit) in two drop tanks. By 18.1.60, three versions of same basic layout – all 66ft 7in (20 3m) long, 29ft (8 8m) folded span. Span with drop tanks 'A' 41ft (12.5m), 'B' 43ft 6in (13.3m), 'D' 44ft (13.4m), wing area with tanks: 'A' 312ft (29 0m), 'B' 419ft (39.0m), 'D' 399ft (37.1m), basic equipped weight, 'A' 28,624lb (12,984kg), 'B' 30 288lb (13,739kg), 'D' 26,581lb (12,057kg) take-off weight in strike and interceptor roles: 'A' and 'B' both 48,000lb (21 773kg) 'D' as interceptor 47,860lb (21,709kg) To carry Bullpup Draft brochure expected 26.2 60 but has not been traced

579 Number allocated to English Electric-built TSR.2s

581 A series of naval and RAF strike aircraft designs to specification ER 206 and OR.346 including adaptations of TSR 2, 1959 60

582 Twin-fuselage strike aircraft to OR.346 first quarter 1960

583 VG naval strike fighter to AW 406, mid-1961 onwards. Also acted as pre-development aircraft for OR 346

584 VSTOL strike aircraft to NBMR 3, 12.61 Tri-service aircraft (NATO, RAF, RN), also to OR.345

585 Begun as naval derivative of Type 584, mid-1961. Became single-engine close support aircraft

Note: Types 586 and 587 were Mach 2 VG airliner studies as part of all-embracing research by the company into swing wings

588 VG research aircraft – Lightning (and Swift) with VG wings, mid-1961.

589 VG research aircraft, all-new airframe, de-militarised Type 590 Also formed part of work to NBMR-3, 2 62.

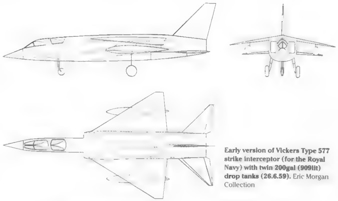
590 Strike aircraft to OR.346, mid-1962 onwards. Also covered naval side of research needs. Was production version of Type 589

591 High Mach number development of Type 589 to OR.355, mid-1962 onwards

592 No information

593 Small experimental VG aircraft, 4.64.

594 Believed allocated to Preston TSR.2 production.



Early version of Vickers Type 577 strike interceptor (for the Royal Navy) with twin 200gal (909lit) drop tanks (26.6.59). Eric Morgan Collection

WESTLAND

A company that never actually built a pure jet bomber (production Wyverns were turboprop powered), but the company was in fact designing jet aircraft by the middle of World War Two. This work was done by W E W Petter and gave experience prior to his move to English Electric where it was put to good use on the Canberra.

P.1056 & P.1061 Fighter-bomber projects, 3.44. Similar configurations with twin MetroVick F 2 4 jets in centre fuselage.

W.34 Wyvern long-range strike to N 11 44 RR Eagle piston engine. First flew 12 12.46.

W.35 Wyvern with RR Clyde or AS Python turboprop to N 12 45, first flew 18 1 49 Other developments to specification had Napier Nomad compound engine or Napier E.141 Eland double turboprop.

W.36 Wyvern development with either 6,500lb (28.9kN) RR AJ.65 or 7,000lb (31.1kN) MetroVick F.9 jets to N.12 45. Span 44ft (13 4m), wing area 360ft (33.5m²), all-up-weight AJ 65 19,000lb (8,618kg), F.9 20,000lb (9,072kg). Fuselage and tail basically as W 34, tricycle undercarriage Four 30mm Aden.

GR.17/45 Twin-engine anti-submarine patrol aircraft, competitor to Fairey Gannet, 1946.

NR/A.32 Light anti-submarine aircraft to NR A.32, two layouts, mid-1950.

M.148T Naval strike aircraft to M 148T, 9.54.

A Westland Wyvern, possibly VW872, armed with rocket projectiles.

Post-War British Bomber Project Specifications

The Air Ministry (the main functions of which were absorbed into a reconstituted Ministry of Defence in April 1964) has traditionally signalled expected future requirements to the British aircraft industry via a series of specifications against which tenders were invited.

Until the end of 1949 the sequential system used to issue these specifications was a letter/number/year arrangement. A typical example is B.9/48 for a Medium-Range Bomber (in fact what became the Vickers Valiant): B stood for bomber; '9' indicated it was the 9th specification issued in that year, which was 1948. Alternative prefix letters included F (fighter), E (experimental) or N (naval).

From 1950 the system changed and at the same time was declared 'Secret' in an effort to prevent any public insight into the thoughts of the Air Council and Admiralty. The new specifications were also prefixed by letters which again indicated the intended role of the aircraft, e.g. B, F, N, plus ER (experimental research), FGA (fighter ground attack), GAR or GR (ground attack, reconnaissance), M (maritime), MR (maritime reconnaissance), SR (strike reconnaissance), T (trainer) or UB (unmanned bomber). The second element was a number in a series that began at 100 and which by the 1980s had passed 300. A suffix letter, for example T (for tender), D (development) or P (prototype), usually completed the specification. There was no longer any reference to indicate the year of issue.

B.104D was one of the first of these new-style specifications to be issued and was written for the Vickers Type 673 Valiant Mk.2 Pathfinder. In the case of B.126T, the suffix 'T' indicated that this was the basic document to which industry would tender for a planned low-level bomber and if one of the tendered designs had been ordered, then a more detailed B.126D would have been written around it.

Specifications for an aircraft required for military service were usually accompanied by an Operational Requirement with its own 'OR' number, for example OR.314 in the case of B.126. In later years 'OR' could be substituted by AST (Air Staff Target), ASR (Air Staff Requirement), NAST or NASR (Naval Air Staff Target/Requirement) or SR/A (Staff Requirement/Air). Separate naval requirements were covered by NR/As, e.g. NR/A.39 for M.148 (Blackburn Buccaneer), although many books and papers prefer to write this as NA.39. Further details of pre-1950 specifications can be found in *The British Aircraft Specifications File* by Meekcoms and Morgan; details of ORs appeared in *Aeromilitaria*, issues April 1996 and January 1997 – all published by Air-Britain.

B.3/45 (OR.199) English Electric A.1 Canberra.
GR.17/45 (OR.220) Blackburn B.54 (Y.A.5), Fairey Type Q (later Type 17 and then Gannet), Westland GR.17/45.
R.5/46 (OR.200) Avro Shackleton.
R.5/46/Iss. III (OR.320) Avro Shackleton Mk.3, Canadair CL.28, Saro P.162.
(OR.230) Bristol Type 172, Short S.A.4, Handley Page HP.72A HP.80.
B.14/46 (OR.239) Short S.A.4 Sperrin.
B.35/46 (OR.229) Armstrong Whitworth AW 56, Avro 698, English Electric B.35 46, Handley Page HP 80, Short S B.1, Vickers B.35 46; *Also* de Havilland DH.111.
B.5/47 (OR.235) English Electric Canberra B Mk.2.
E.8/47 (OR.250) Bristol Type 174; **E.8/47/II** Bristol Type 176.
R.2/48 (OR.231) Blackburn B.78, Saro P.162, Short P.D.2, Supermarine Type 524.
E.6/48 Handley Page HP.88.
B.9/48 (OR.229) Vickers Type 660 Valiant.
E.15/48 Avro 707
B.22/48 (OR.263 & OR.302) English Electric Canberra B Mk.5.
M.6/49 (NR/A.9 & OR.275) Short S.B.3.
(NR/A.18) Variant of de Havilland N.40/46 fighter (?).
(NR/A.19) Variant of Fairey N.40/46 fighter, Supermarine Types 522 & 537.
E.10/49 Avro 707B.
E.11/49 Avro 698 'flying shell' or Avro 710.
B.104D (OR.285) Vickers Type 673 Valiant Pathfinder.
UB.109T (OR.1097) Boulton Paul P.123, Bristol Type 182, Vickers Type 725
GR.117P (OR.220) Fairey Gannet AS Mk.1
M.123D & P (NR/A.32) Blackburn B.83 & B.91, Short P.D.4 (S.B.6) Seamew, Westland M.123.
B.126 (OR.314 & OR.324) Avro 721, Bristol Type 186, Handley Page HP.99, Short P.D.9.
B.128P Handley Page Victor B Mk.1
B.129P Avro Vulcan B Mk.1.
M.148T (NR/A.39) Armstrong Whitworth AW.168, Blackburn B.103, Fairey M.148, Hawker P 1108, Short P.D 13, Westland M.148; *Also*(?): Saro P 178
(OR.328 Draft only) Gloster Thin Wing Javelin.
R.156 (OR.330) Avro 730, English Electric P.10, Handley Page HP.100, Short P.D.12, Vickers R.156; *Also:* Saro P.188.
(OR.336) Long-range high-altitude bomber – studies only
(GOR.339) *Interim*: Blackburn B.103A, de Havilland DH 110, Hawker P 1121, Vickers (Supermarine) Type 565.
Full: Avro 739, Blackburn B.108, Bristol Type 204, de Havilland GOR.339, English Electric P.17, Fairey GOR.339, Hawker P.1129, Vickers (Supermarine) Type 571 (two designs; *Also*: Gloster Thin Wing Javelin, Handley Page study, Combined Avro 739/Hawker P.1129 project.
ER.180D Avro 731
RB.192D (OR.343) BAC TSR.2.
(ASR.343) General Dynamics F-111K.
ER.204D (GOR.345) Hawker P.1127.
ER.206 (OR.346) Blackburn B.123, de Havilland DH.127, Hawker P.1151, P.1152 & P.1153, Vickers (Supermarine) Types 581, 582, 583, 589 & 590.
GAR.214D (OR.345) Ground attack aircraft. 'In hand' 1960-63 but abandoned.
MR.218 (OR.350) Avro 776, Avro Shackleton development, Breguet Atlantic, versions of the BAC Vanguard and VC-10 airliners, versions of the Hawker Siddeley Comet and Trident airliners
B.222P Avro Vulcan Mk.2 with Skybolt.
M.232D & P Hawker Siddeley Buccaneer Mk.2 (1963).
FGA.236D & P Hawker Siddeley Kestrel.
(OR.354) TSR.2 replacement – studies only.
(OR.355 & AST.355) TSR.2 and Buccaneer replacement – studies only.
F.242 (later SR.250D & P) (NASR[OR].356) Hawker Siddeley P.1154, RAF & RN.
(AST.357) Various including Short P.D.69.
(AST.362) BAC P.45 variants, Hawker Siddeley HS.1170B, HS.1171, HS.1173
(ASR.362) SEPECAT Jaguar
(ASR.380) Low-level V-bomber operations.
MR.254 (ASR.381) Hawker Siddeley HS.800, Hawker Siddeley HS 801 Nimrod.
SR.255D & P (ASR.384) Hawker Siddeley Harrier GR Mk.1.
M.258D & P Hawker Siddeley Buccaneer Mk.2 (1965).
260 (ASR.388) Anglo-French Variable Geometry Aircraft (AFVG, *Also*: BAC UK Variable Geometry Aircraft (UKVG).
(ASR.392) Panavia Tornado GR Mk.1.
(AST.396 Iss. 1) BAC P.66, P.69, P.70, P.71, P.72, P.73 & P.74, Hawker Siddeley HS.1182-74, HS.1189 & HS.1190.
(AST.396 Iss. 2) BAC P 76, P.77, P.78 & P 79, Hawker Siddeley HS.1195-4 & HS.1197.
GR.297 (ASR.409) BAe Harrier GR Mk.5.
(SR/A.417) Panavia Tornado GR Mk.4.
(SR/A.420) BAe Nimrod 2000
(SR/A.425) Future Offensive Air System (FOAS).

Post-War British Bomber Contracts

Type	*Serials*	*Contract*	*(Date)*
EE Canberra B Mk.1	VN799, VN813, VN828, VN850	Acft 5841 CB.6(b)	(10.12.45)
EE Canberra B Mk.2 & 5	VX165, VX169, VX173, VX177, VX181, VX185	6 Acft 2000 . . .	(22.1 48)
Avro Shackleton	VP253-268, VP281-294	Acft 6062 C 4(a)	(9.3 46)
	VW126, VW131, VW135	6 Acft 1077 CB.6(a)	(17.7.47)
Fairey Gannet	VR546, VR557	6/Acft/494/CB.9(b)	(31.7.46)
	WE488	6/Acft/3874/CB.9(a)	(19.7.49)
Short S.A.4 Sperrin	VX158, VX161	6/Acft/656/CB.6(b)	(19.1.48)
Bristol Type 174	VX317, VX323	6/Acft/1308/CB.6(b)	(5.4.48)
Avro 698	VX770, VX777	6/Acft/1942/CB.6(a)	(22.6.48)
Avro 707	VX784, VX790	6/Acft/2205/CB.6(b)	(22.6.48)
Avro 707A	WD280	6/Acft/3395/CB.6(b)	(6.5.49)
Avro 707A & C	WZ736, WZ739, WZ744	6/Acft/7470/CB.6(a)	(13.11.51)
Avro 710	VX799, VX808	6/Acft/2626/CB.6(b)	(22.6.48)
Handley Page HP.80	WB771, WB775	6/Acft/1875/CB.6(a)	(11.3.49)
Handley Page HP.88	VX330, VX337	6/Acft/2243/CB.6(b)	(5.4.48)
Blackburn Y.A.7 etc	WB781, WB788, WB797	6/Acft/822/......	(14.3.49)
Vickers B.9/48	WB210, WB215	6 Acft 2339 . . .	(10.12.48)
Vickers Valiant B Mk.2	WJ954	6 Acft 5957 CB.6(b)	(1 11 50)
Short S.B.3	WF632, WF636	6 Acft 3955	(6.4.50)
Short S.B.1/S.B.4	No known official contract		
Short S.B.6 Seamew	XA209, XA213, XA216	6 Acft 7762 CB.9(a)	(3.52)
Blackburn B.103	XK486-491, XK523-536	6 Acft 11790 CB.9(a)	(2 6.55)
Avro 730/731	No serials allotted		
Hawker P.1127	XP831, XP836	KD 2Q 02 CB 9(c)	(14.6.60)
	XP972, XP976, XP980, XP984	KC 2Q/02 CB.9(c)	(12.8.60)
HSA Kestrel	XS688-696	KC 2Q/016 CB 9(b)	(2.7.63)
Hawker P.1154	No serials allotted		
HSA Harrier	XV276-281	KC 3G 02 CB.9(b)	(8.3.66)
BAC TSR.2	XR219-227,	KD 2L 02 CB.42(a)	(10.10.60)
	XS660-670	KD 2L 13 CB.42(a)	(14.6.63)
HSA Nimrod	XV147, XV148	KD G 64 CB.6(b)	(17.9.65)
SEPECAT Jaguar	XW560, XW563, XW566	'Av Sec. 2A'	(15.10.68)
AFVG	No serials allotted		
General Dynamics F-111K	XV884-887, XV902-947		(8.8.67)
Panavia MRCA/Tornado GR Mk.1	XX946-948, XX950	NAMMO BCL C/3100 71/NU	(19.7.73)

The date gives the point where serials were allocated and comes from the Ministry's serial ledger. It should fall very close to the date of an ITP, which was the official authority to spend money, but some of the dates given above come after the start of work on their particular project, even to the point where preparations were under way for metal bashing. In such cases the company concerned may have begun work as a private venture or short-term contracts may have proceeded the ITP.

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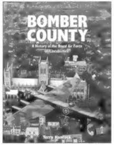

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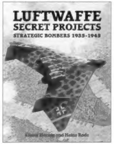

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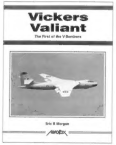
VICKERS VALIANT
The First V-Bomber

Eric B Morgan



The Valiant was the shortest-lived of the post-war V-bombers, first flying in 1951 and with production of 104 aircraft ending in 1957, and official withdrawal in January 1965 after investigation had shown that the main wing spars were suffering from metal fatigue. Valiants participated in British atomic bomb tests and made noteworthy long-distance flights, principally operating from Marham and Gaydon. Includes a full listing of each aircraft history.

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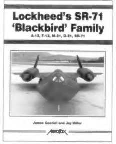
A-12, F-12, M-21, D-21, SR-71

James Goodall and Jay Miller



Though only 50 of these craft were built, everything about them was unique. The stories of the development program, the General Dynamics 'Kingfish' competition, the M-21 and D-21 effort, the F-12 saga, and the operational history of the A-12 and SR-71 under the auspices of the CIA and the USAF are all covered in detail. The high-speed, high-altitude recce overflights performed by SR-71As from bases in the US, Japan and the UK during the Cold War are also covered.

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The Soviet Union's First Production Supersonic Fighter

Yefim Gordon

The MiG-19 'Farmer' represented a major technological leap for the VVS as it was one of their first fighters to accommodate AAMs, ground control intercept system and other advances. By the end of the 1950s it became their standard fighter and was integrated into the inventories of most Warsaw Pact countries and Soviet allies. It was produced in thousands in the USSR, Czechoslovakia and China (J-6, JJ-6 & Q-5); export customers included Cuba, Egypt, Albania, Vietnam and Pakistan.

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Sweden's 21st Century Multi-role Aircraft

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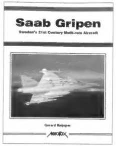

Today's Swedish Air Force has as its spearhead the Saab Gripen. A fourth-generation fighter that embraces state-of-the-art technology, the Gripen offers an impressive multi-role capability – air defence, attack, reconnaissance – making it a more than worthy successor to the mighty Viggen and elegant Draken.
First flown in 1988, early problems were overcome and operational capability was achieved in October 1997. Foreign sales have been made or are in prospect.

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Red Star Volume 7
TUPOLEV Tu-4 SOVIET SUPERFORTRESS

Yefim Gordon and Vladimir Rigmant

At the end of WW2, three Boeing B-29s fell into Soviet hands; from these came a Soviet copy of this famous bomber in the form of the Tu-4. This examines the evolution of the 'Superfortresski' and its further development into the Tu-70 transport. It also covers the civil airliner version, the Tu-75, and Tu-85, the last of Tupolev's piston-engined bombers. Also described are various experimental versions, including the Burlaki towed fighter programme.

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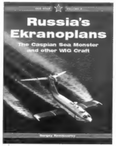
RUSSIA'S EKRANOPLANS
Caspian Sea Monster and other WIG Craft

Sergey Komissarov



Known as wing-in-ground effect (WIGE) craft or by their Russian name of ekranoplan, these vehicles operate on the borderline between the sky and sea, offering the speed of an aircraft coupled with better operating economics and the ability to operate pretty much anywhere on the world's waterways.
WIGE vehicles by various design bureaus are covered, including the Orlyonok, the only ekranoplan to see squadron service, the Loon and the KM, or Caspian Sea Monster.

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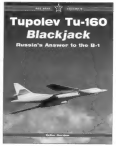
Red Star Volume 9
TUPOLEV Tu-160 BLACKJACK
Russia's Answer to the B-1

Yefim Gordon



How the Soviet Union's most potent strategic bomber was designed, built and put into service. Comparison is made between the Tu-160 and the Sukhoi T-4 ('aircraft 100', a bomber which was ahead of its time), the variable-geometry 'aircraft 200' – and the Myasishchev M-18 and M-20.
Included are copies of original factory drawings of the Tu-160, M-18, M-20 and several other intriguing projects. Richly illustrated in colour, many shots taken at Engels.

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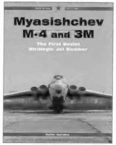
Red Star Volume 11
MYASISHCHEV M-4 and 3M
The First Soviet Strategic Jet Bomber

Yefim Gordon



The Soviet Union's first intercontinental jet bomber which was to have become a carrier of nuclear missiles and the Soviet answer to the B-52. Known to the West as the *Bison*, it employed many innovative features and was created in just one year. The M-4 and the much-improved 3M remained in service for 40 years until retired and scrapped in compliance with the START treaty.
Also described are the many projected derivatives of the M-4 designed in the 1950s, including long-range airliners.

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Model of English Electric's submission to V-Bomber Specification B.35/46 (29.3.47).

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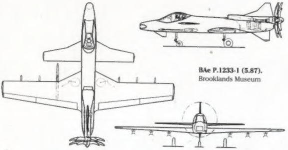
Had it been produced, the DH.127 would have entered service aboard Royal Navy carriers in the 1970s. Artwork by Pete West

Hawker Siddeley's group submission to GOR.339 lost out to what became the BAC TSR.2. Artwork by Pete West

The HP.99 was the Handley Page response to Specification B.126T and OR.324 for a high-speed low-altitude bomber. Artwork by Pete West



BAe P.1233-1 (5.87). Brooklands Museum

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